Weeds

VOLUME V
OCTOBER 1957
NUMBER 4

Journal of the Weed Society of America

Weeds

Issued Quarterly by the Weed Society of America

K. P. BUCHHOLTZ, *Editor*, Dept. of Agronomy, Univ. of Wisconsin, Madison, Wisconsin.

W. C. JACOB, *Business Manager*, Dept. of Agronomy, Univ. of Illinois, Urbana, Illinois.

EDITORIAL COMMITTEE

R. J. ALDRICH, Weed Investigations Section, USDA, Rutgers Univ., New Brunswick, New Jersey.

O. C. LEE, Dept. of Botany and Plant Pathology, Purdue Univ., Lafayette, Indiana.

W. C. ROBOCKER, Weed Investigations Section, USDA, State College of Washington, Pullman, Washington.

W. K. PORTER, JR., Dept. of Plant Pathology, Univ. of Louisiana, Baton Rouge, Louisiana.

WEEDS is a quarterly journal published by the Weed Society of America. Editorial offices are located at the University of Wisconsin, Madison, Wisconsin. Printing is by the W. F. Humphrey Press Inc., Geneva, New York. Subscription price is $6.00 yearly for four issues: single copies $1.50. Address all communications regarding subscriptions, advertising and reprints to W. C. Jacob, Department of Agronomy, University of Illinois, Urbana, Illinois. Inquiries concerning information on manuscripts and other material for publication should be addressed to the Editorial Offices. All checks, money orders and other remittances should be made payable to the Weed Society of America.

Entered as second-class matter at the post office at Urbana, Illinois with additional entry at Geneva, New York.

Table of Contents

	Page
Effect of Phenoxy Herbicide Concentrates Applied to Cuts of Sprouting Tree Species. O. A. Leonard	291
Amino Triazole Salts and Amino Triazole-5-C^{14} Studies on Pigment Production in Cotton. C. S. Miller and Wayne C. Hall	304
Some Effects of 2,2–Dichloropropionic Acid on Soil Microorganisms. A. D. Worsham and Joel Giddens	316
The Leaching of Monuron from Lakeland Sand Soil. Part I. The Effect of Amount, Intensity, and Frequency of Simulated Rainfall. R. P. Upchurch and W. C. Pierce	321
The Effects of Several Herbicides on Nitrification in a Field Soil Under Laboratory Conditions. M. G. Hale, F. H. Hulcher and W. E. Chappell	331
Interception of Herbicidal Sprays by Oats and its Relation to Alfalfa Stands. K. P. Dorschner and K. P. Buchholtz	342
The Effects of Wind on Delivery Patterns of Nozzles used for Weed Spraying. M. J. Morgan, L. W. Rasmussen and L. W. Orton	350
Pre-emergence Weed Control in Soybeans. Henry W. Indyk	362
Brief Papers	
A Laboratory Test for Screening Chemicals for Toxicity to Submerged Aquatic Plants. M. S. Hudson and Bee Hudson	371
News and Notes	374
Bibliography of Weed Investigations, January to March, 1957	375
Index Volume V	393
Sustaining Members	x

Advertisers Index

Union Carbide Chemicals Co.	ii
duPont de Nemours & Co.	iii
U. S. Borax & Chemical Co.	iv
Standard Agricultural Chemicals Co.	v
Diamond Alkali Co.	vi
Chipman Chemical Co.	vii
American Cyanamid Co.	viii
Spraying Systems Co.	ix

Make your own tests with these

CRAG BRAND **HERBICIDES**

SAMPLES of the CRAG Herbicides listed below are available for experimental purposes.

CRAG Mylone 85W is an easy-to-handle, pre-planting soil fumigant for control of weeds, soil fungi and nematodes. We suggest you test it on **tobacco, vegetable** and **conifer seed beds.** Now commercially used on ornamental propagating beds. No plastic cover is needed.

CRAG DCU 73W has controlled annual grasses up to three months when mixed with the top layer of soil before planting, in tests. We suggest you test it on **sugar beets** and **cucurbits.**

CRAG Sesone is an economical weed-seed toxicant which is activated upon soil contact. We suggest you test it for weed control in growing **peanuts, strawberries, nursery stock, potatoes, asparagus,** and **corn for seed.**

CRAG AGRICULTURAL CHEMICALS ARE PRODUCTS OF

Union Carbide Chemicals Company

DIVISION OF UNION CARBIDE CORPORATION

30 East 42nd Street, New York 17, N. Y.

"Crag", "Mylone", "Sesone", and "Union Carbide" are trade-marks of Union Carbide Corporation.

MAIL THIS COUPON NOW

CRAG Agricultural Chemicals
UNION CARBIDE CHEMICALS COMPANY
30 East 42nd Street, New York 17, New York

Please send additional information and your application blank for an experimental sample of CRAG Mylone 85W_____ CRAG DCU 73W_____ and CRAG Sesone_____

Name_____

Address_____

City_____ State_____

For Agriculture and Industry . . .

Du Pont
UREA HERBICIDES

offer new economies and efficiency in killing weeds, grass and brush

"KARMEX" for weed control in asparagus, sugar cane, pineapple, potatoes, grapes, alfalfa, citrus and other crops. Also for irrigation and drainage ditch weed control. Available in two formulations: "Karmex" W monuron and "Karmex" DW diuron.

KARMEX® DL for pre-emergence weed control in cotton.

TELVAR® for industrial weed and grass control. Also in certain areas, it is recommended for brush control. "Telvar" W monuron and "Telvar" DW diuron.

The urea herbicides, products of Du Pont research, kill vegetation through the roots. Their efficiency is demonstrated by the relatively low dosages required to do the job. They can be easily applied, are non-flammable, non-volatile, non-corrosive and extremely low in toxicity.

DU PONT

Better Things for Better Living *Through Chemistry*

E. I. DU PONT DE NEMOURS & CO. (INC.)

GRASSELLI CHEMICALS DEPT.

WILMINGTON 98, DELAWARE

Four easy ways to Destroy Weeds

1. UREABOR®

A nonselective, granular complex of sodium borate and substituted urea. Low application rates are a feature. Apply with the special new PCB Spreader for best results.

2. DB® Granular

A combination of 2,4-D and sodium borates. Kills deep-rooted, noxious weeds. Low application rates for maximum control with the utmost economy; use the PCB Spreader. *(Not intended for control of grass.)*

3. POLYBOR-CHLORATE®

Highly soluble; for spray or dry application. It gives a quick knock-down; destroys top growth and roots. A general nonselective herbicide.

4. Concentrated BORASCU®

A nonselective, granular material. Apply by hand or with a mechanical spreader. Long residual action.

When you want Nonselective Herbicides for Dependable Action

look to United States Borax & Chemical Corporation

PACIFIC COAST BORAX COMPANY DIVISION

630 Shatto Place, Los Angeles 5, Calif.
100 Park Avenue, New York 17, N.Y.

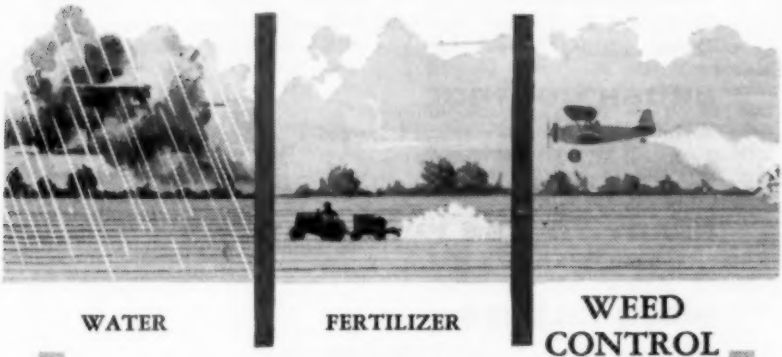
SINOX...

the standard weedkiller

Like water and fertilizer, weed control is vital to all agriculture. And SINOX formulations, products of combined field experience and laboratory research, are the *first choice* for positive weed control.

SINOX PE, for pre-emergence spraying of potatoes, beans, corn and peas; also control of winter annuals in fall seeded alfalfa, and clover.

SINOX GENERAL is a hard-hitting dinitro for clearing



WATER FERTILIZER WEED CONTROL

vines, ditches, roadsides, and general weed destruction. Useful also as a dessicant for seed alfalfa, clover, Sudan grass, flax and milo.

SINOX W is highly efficient for selective spraying of seeding alfalfa, onions, flax, peas, and grain seeded to legumes.

We are devoted to progress in weed control at Standard Agricultural Chemicals, and are helping to create a new era in weed control for *you*. Keep up to date on latest developments by checking with us directly.

STANDARD Agricultural **CHEMICALS**
INCORPORATED
1301 Jefferson Street, Hoboken, New Jersey
429 Forum Building, Sacramento, Calif.

Whatever your control problem, Diamond has the solution!

As one of the world's largest makers of herbicides, DIAMOND ALKALI has the experience and facilities to help you select the right chemical formulation for any job. Write DIAMOND ALKALI COMPANY, 300 Union Commerce Bldg., Cleveland 14, Ohio.

TECHNICALS

for formulators and processors

WEED KILLERS

2,4-D Acid • Technical Butyl-D
Technical Isopropyl-D
Technical 2-Ethyl Hexyl (Iso-Octyl)-D (Low Volatile)
Technical BEP-D (Low Volatile)

BRUSH CONTROL

Technical Butyl-T • Technical Isopropyl-T
Technical BEP-T (Low Volatile)
Technical 2-Ethyl Hexyl (Iso-Octyl)-T (Low Volatile)

READY-TO-USE FORMULATIONS

for farms, ranches, orchards, parks, homes

WEED KILLERS

*4# Mixed Amine-D • 4# Dimethylamine-D
2.67# Butyl-D • 4# Butyl-D • 6# Butyl-D
4# 2-Ethyl Hexyl (Iso-Octyl)-D (Low Volatile)
4# BEP-D (Low Volatile) • 3.34# Isopropyl-D

BRUSH CONTROL

*4# Butyl-T • 4# BEP-T (Low Volatile)
4# 2-Ethyl Hexyl (Iso-Octyl)-T (Low Volatile)
2,4-D—2,4,5-T Mixtures • 2#—2# Butyl Brush Killer
2#—2# 2-Ethyl Hexyl Brush Killer (Low Volatile)
2#—2# BEP Brush Killer (Low Volatile)

**Numbers are pounds of 2,4,5-T or 2,4-D acid equivalent per gallon.*

DIAMOND CHEMICALS®

Diamond Chemicals

ATLACIDE: A chlorate weed killer ...widely used for non-selective eradication of bindweed, Canada thistle, quack grass, Johnson grass and other tough perennials. Kills roots...discourages regrowth. Applied as spray or in original dry form.

ATLACIDE WITH 2, 4-D: A combination of Atlacide and 2,4-D acid. Particularly recommended for Canada thistle control.

CHLOREA: A uniform, non-separating combination of sodium chlorate, borate and CMU. Kills *all* types of weeds and grasses. Combines the proven effectiveness of chlorate on deep-rooted weeds with the soil-surface action of CMU on shallow-rooted grasses and annual seedling growth. Has lasting residual effect to inhibit new growth. Does not create a fire hazard when used as directed. Applied dry or as a water-mixed spray. For industrial, railroad and certain agricultural uses.

CHLORAX "40": A non-separating composition of sodium chlorate and borate...for weed and grass control. Has a lasting residual effect. Does not create a fire hazard. Applied dry or as a spray.

CHLORAX LIQUID: Similar to Chlorax "40"...in liquid form for easy mixing with water.

ATLAS "A": A 40% sodium arsenite solution (4 lbs. arsenic trioxide per gal.). Destroys certain submersed vegetation in ponds and lakes. Controls crabgrass, chickweed and clover in turf. Used as general weed killer and to kill trees and stumps. Also used to kill potato vines prior to harvesting.

SODIUM ARSENITE: A powder containing 75% arsenic trioxide. Used for the same purposes as Atlas "A". Applied dry or as a spray.

2, 4-D WEED KILLERS: A complete line—Available as 2,4–D Amine and 2,4–D Ester liquids; also 2,4–D Ester dusts.

METHOXONE: Contains 2 pounds of MCP sodium salt per gallon. Used for weed control in small grains, flax, rice and grass. Controls same weeds as 2,4-D; considered safer for selective spraying.

Low Volatile 2,4,5-T
Low Volatile Brush Killer
Chloro IPC • IPC 25% Liquid

Write for Weed Control Booklets

CHIPMAN CHEMICAL COMPANY, INC.

Chicago, Ill. BOUND BROOK, N. J. Portland, Ore.
Palo Alto, Calif. . Pasadena, Tex. . Bessemer, Ala.

Manufacturers of Weed Killers Since 1912

A Cyanamid Report

Amino Triazole Weedkiller* passes first test

Amino Triazole Weedkiller has had one season of farm use for killing deep-rooted perennials. This experience justifies firmer confidence in this new chemical as a control for Canada thistle, horsetail rush, poison ivy, cattails, woody plants, and many other species. Production has been increased to meet demand in 1957.

Much interesting research yet to be done

In spite of the impressive amount of research completed during the past 4 years by State and Federal workers, we have only partial answers as to how and why this systemic herbicide does what it does to plants:

1. Why is Amino Triazole so readily absorbed into plant foliage?
2. Why is Amino Triazole translocated so readily downward and laterally throughout the plant compared to other systemic herbicides?
3. What are metabolites of Amino Triazole in the plant?
4. How does Amino Triazole destroy and interfere with the formation of chlorophyll?
5. What vital growth processes are affected, causing death of plants?
6. Why are certain species relatively so much more sensitive to Amino Triazole than others?

We will be glad to supply the latest data to those interested in working with this new herbicide.

CYANAMID

*3-amino-1, 2, 4-triazole

Send coupon for complete information and technical data

AMERICAN CYANAMID COMPANY
Agricultural Chemicals Division, Dept. W
30 Rockefeller Plaza, New York 20, N. Y.

Please send more information and technical data on Amino Triazole Weedkiller.

NAME .....

STREET .....

CITY ..... STATE .....

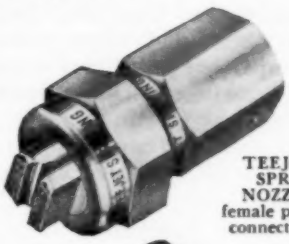
SPRAYING SYSTEMS

TeeJet SPRAY NOZZLES

the precision nozzle for effective spraying

Supplied in a full range of interchangeable orifice tip and strainer sizes to meet every capacity requirement. TeeJet Spray Nozzles for Weed Control by spraying make it possible to take maximum advantage of the chemical and sprayer unit. TeeJet nozzles are precision built and provide a flat spray with uniform distribution. Atomization is properly controlled to give coverage with an absolute minimum of driftage. Patented tip design, with set-back orifice opening protects precision orifice from accidental damage. TeeJet spray nozzles are built for use on spray booms and portable sprayers.

TEEJET SPRAY NOZZLE male pipe connection



TEEJET SPRAY NOZZLE female pipe connection

INTERCHANGEABLE ORIFICE TIPS flat and cone spray types

OFF-CENTER SPRAY NOZZLES

Spraying Systems Spray Nozzles with TeeJet tips are supplied in a variety of special body types to meet any unusual spraying requirement. For example, one type of off-center spray nozzle with swivel body provides a flat spray up to 35 feet wide for spraying areas with a single nozzle, that are not accessible with a boom.

SUPPLEMENTARY EQUIPMENT

Complete accessories relating to nozzle use are supplied. These include strainers, special nozzle fittings, and hand valve equipment.

TeeJet Spray Nozzles are supplied for Weed Control... as well as all other types of agricultural spraying. For complete information and reference data write for Catalog 30.

SPRAYING SYSTEMS CO.

Engineers and Manufacturers

3296 RANDOLPH STREET BELLWOOD, ILLINOIS

Sustaining Members

American Chemical Paint Company, Ambler, Pennsylvania
American Smelting and Refining Co., Central Research Laboratories, South Plainfield, New Jersey
Asplundh Tree Expert Company, Jenkintown, Pennsylvania
Association of American Railroads, Chicago, Illinois
Chemical Insecticide Corp., Brooklyn, New York
Chipman Chemical Company, Inc., Bound Brook, New Jersey
Crag Agricultural Chemicals Division, Carbide and Carbon Chemicals Co., New York, New York
Deere and Company, Product Research Dept., Moline, Illinois
Diamond Alkali Company, Cleveland, Ohio
The Dow Chemical Company, Midland, Michigan
E. I. duPont deNemours & Company, Inc., Grasselli Chemicals Dept., Wilmington, Delaware
G.L.F. Soil Building Service, Ithaca, New York
Geigy Agricultural Chemicals, Div. of Geigy Chemical Corp., Yonkers, New York
Hercules Powder Company, Wilmington, Delaware
International Harvester Company, Chicago, Illinois
Monsanto Chemical Company, St. Louis, Missouri
National Aluminate Company, Chicago, Illinois
Olin Mathieson Chemical Corp., Baltimore, Maryland
O. M. Scott and Sons Company, Marysville, Ohio
Spraying Systems Company, Bellwood, Illinois
Stauffer Chemical Company, New York, New York
Swift and Company (Plant Food Division), Chicago, Illinois
United States Borax and Chemical Corp., Los Angeles, California

Weeds

JOURNAL OF THE WEED SOCIETY OF AMERICA

VOLUME V OCTOBER 1957 NUMBER 4

Effect of Phenoxy Herbicide Concentrates Applied to Cuts of Sprouting Tree Species

O. A. LEONARD[1]

SOME data have already been presented (6) on the kill of blue oak (*Quercus douglasii* H. & A.) with concentrates of 2,4–dichlorophenoxyacetic acid (2,4–D) and 2,4,5–trichlorophenoxyacetic acid (2,4,5–T) applied to cuts in the trunks. The present paper is concerned with reporting some similar studies on species which are noted for being persistent or vigorous sprouters. Since the sprouting question represented an important part of these studies, it was necessary to make observations for several years after treatment to arrive at some relatively dependable conclusion concerning effectiveness.

Most of the data in this report have been collected from studies on interior live oak (*Quercus wislizenii* A. DC.); however, sufficient data are presented on black oak (*Quercus kelloggii* Newb.) and madrone (*Arbutus menziesii* Pursh.) to indicate the effect on these species. Interior live oak is the most difficult of the three species to control by conventional methods; it is, also, the most difficult to control by chemical means. It is widely distributed on rangelands and potential rangelands. Black oak and madrone are problems on rangelands and in forested areas.

Interest in studying the cut-surface method of control is due to several factors. Perhaps the most important reason for interest in the method is due to the very poor kills that have been obtained thus far by aircraft application. Not one single tree of interior live oak has been killed by aircraft application in tests conducted by the author and the kills of black oak and madrone have not be satisfactory. One desirable feature of the method is that it is as selective as the user desires to make it and the chemical costs are only 1 or 2 cents for trees 1 foot in diameter.

Because of their evergreen foliage, live oak and madrone exclude or nearly exclude the growth of grass beneath them. Although black oak is deciduous, grass growth is only moderate to sparse beneath this species. Within 2 or 3 years after treatment, a good cover of grass develops beneath all of the above species.

[1]Associate Botanist, University of California, Davis, California.

METHODS AND MATERIALS

Most of the tests reported in this paper were conducted in 1951 and 1952 on the L. J. Gamble and George Gamble ranch in Napa County and on the John Allen ranch in Amador County. The remaining tests reported were conducted on the University of California's Hopland Experimental Range.

The trees varied in diameter from 6 to 36 inches and frequently consisted of two or more stems, especially the live oak and the madrone (about 25% of the trees). The multiple stemmed trees were generally the result of fire at some time in the past, which killed the tops of the original trees, resulting in the development of crown sprouts. Some of these sprouts eventually became large, resulting in multiple stemmed clumps. Live sprouts present near the bases of some of the trees at the time of treatment resulted from ground fires which killed some bark on one side of the tree, causing sprouts to develop.

Cuts were made through the bark into the wood using a sharp hatchet. In 1951, a shingle hatchet having a blade 2 inches wide was used, but in all subsequent years, a broad bladed heavy hatchet has been used. An attempt was made to drive the blade as deeply as possible into the wood, with only one hit; however, when the bark broke or when a poor cut was made, a second attempt was necessary. The cuts were horizontal to the ground, so the liquid would not run out one end of the cut. Variations in the spacing of the cuts constituted an important aspect of these studies.

When otherwise not designated, "spaced cuts" will refer to cuts spaced in such a manner to make one cut for each 6 inches in stem circumference, with the cuts spaced as uniformly as possible around the trunks. The "continuous cuts" will refer to separate cuts made in such a manner that all of the bark was severed around the tree; however, no attempt was made to have the cuts connect with one another (that is, to be on the same level). The objective was to sever the vertical lines of flow, so that the entire circumference could be treated when the chemical was introduced into the bark and wood. About 50% more cuts were required to make the cuts "continuous" than when the cuts were "spaced" in the normal manner.

A 5 or 10 ml. veterinary hypodermic syringe was used for making the applications. Liquid formulations[2] of 2,4–D, 2,4,5–T, 2–(2,4,5–trichlorophenoxy) propionic acid (2–(2,4,5–TP)) as amines (water soluble) and esters (propylene glycol butyl ether esters), and amines of 2–methyl–4–chlorophenoxyacetic acid (MCPA) and 2–(2,4–dichlorophenoxy) propionic acid (2–(2,4–DP)) were used. All of the formulations contained 4 pounds of acid equivalent per gallon and they were used without dilution with oil or water. Ten trees constituted each single treatment, except as may be noted in the text.

Although readings were usually taken each year after treatment, most of the data presented was that which was recorded after the

[2]Experimental samples supplied by The Dow Chemical Company and American Chemical Paint Company.

longest interval of time after treatment; with black oak and madrone, this was in June 1956 and with interior live oak it was in November 1956.

RESULTS

The results for interior live oak will be considered separately from those of black oak and madrone, because this was the species most extensively studied.

Spacing of the cuts with interior live oak

As is indicated in Table 1, spacing of the cuts had a pronounced effect on top and plant kill. Close spacing of the cuts was clearly more effective than having the cuts spaced further apart. There is, also, an interrelation between dosage and spacing. These tests were conducted in the summer, a time of the year when live oak is most difficult to kill.

Table 1. Effect of spacing of cuts on the kill of live oak. Average effect of 2,4–D and 2,4,5–T amines. Results were recorded 5 years after treatment. Width of the cut was 2 inches.

Spacing[1] in.	Dosage in ml. per cut							
	1 ml.		2 ml.		4 ml.		8 ml.	
	Top kill %	Plant kill %	Top kill %	Plant kill %	Top kill %	Plant kill %	Top kill %	Plant kill %
4	10	10	60	50	90	80	—	—
6	10	10	50	40	80	70	—	—
8	0	0	0	0	40	40	50	30
12	0	0	0	0	10	10	20	10

[1]Spacing indicates distance from center of one cut to the center of the next cut.

Early in these studies, it was found that many of the trees treated with cuts spaced at intervals around the trees developed an imperfect top kill. Some branches would be killed, while others remained more or less unaffected; this suggested the desirability of comparing the results with "spaced" and "continuous" cuts, some results of which are shown in Table 2. Applications of chemicals to continuous cuts resulted in a more consistent kill than when the same materials were applied to spaced cuts. An ester of 2–(2,4,5–TP) resulted in the least kill of any of the chemicals tested.

Approximately 100 trees and clumps of trees were treated with 2,4–D amine applied to continuous cuts in March 1953. As observed 3½ years later, the treated trees had 100% top kill, but approximately 15% had one or more live basal sprouts; therefore, the actual kill was considered to be 85%. It is not known how many of these had sprouts at the time of treatment, but the results certainly indicate that some follow-up type of treatment will be necessary to kill the surviving sprouts. The follow-up that might be done was suggested by one experiment. Four years after the trees were treated, when one-third of the trees had fallen, the site was burned. The fire more or less completely consumed the trees and killed the sprouts.

Table 2. Plant and top kill of live oak by chemicals applied to spaced and continuous cuts. The quantity of chemical used was equal to 1 ml. for each inch of stem diameter.

Treatment date	Chemical used	Spaced cuts		Continuous cuts	
		Top kill %	Plant kill %	Top kill %	Plant kill %
December 1951	2,4–D amine	100	80	100	100
uly 1952	2,4–D amine	50	20	100	70
December 1952	2,4–D amine	100	100	100	100
March 1953	2,4–D amine	70	70	100	100
March 1953	2,4,5–T amine	90	90	100	100
March 1953	2–(2,4,5–TP) ester	20	0	80	40
November 1953	2,4–D amine	100	100	100	90
November 1953	2,4,5–T amine	100	60	100	60
November 1953	2–(2,4,5–TP) amine	90	80	100	90
July 1954	2,4–D amine	90	60	100	100
July 1954	2,4,5–T amine	60	30	90	70
July 1954	2–(2,4–DP) amine	60	40	60	40
July 1954	2–(2,4,5–TP) amine	80	40	100	40

The site is now accessible so that ground spray equipment can be used to treat regrowth.

When the bark is removed from a treated tree a year or more after treatment, the killed tissues indicate the early pathway of movement of the chemical. It is clear that some tissues were quickly killed by the chemical, while other tissues died more slowly and some were still alive. The broadest band of quickly killed wood and bark was directly above and below the cuts. Proceeding upwards, the band became somewhat narrower and could be traced for a considerable distance up the trunk. When the cuts were too shallow —that is, barely into the wood—considerable bark proliferation occurred along the pathway of movement, generally accompanied by poor kills. Progressing downward from the points of application, the movement was erratic, but often continued to the ground, which was as far as could be conveniently traced; obstructions, such as dead branches, appeared to stop the movement. Trees treated in the summer had narrower bands of tissue killed downward from the cuts than trees treated in the winter, as is indicated in Figures 1 and 2.

Figure 1 shows a tree that was treated in the summer, but which was not killed. Cut No. C shows a wedge-shaped kill of wood below the cut, with this merging into a narrow band of killed tissue that extended to the soil line. A broad band of wood was killed below cut No. E. Figure 2 shows a tree treated in the winter that was killed by the treatment and is representative of several hundred similar trees treated by the rancher. The arrows point to some live tissue having a wedge-like shape. Although the tops of all of the trees were killed and no sprouts have developed to date (13 months after treatment), some sprouts can be expected to form from unkilled tissues, such as is indicated by the arrows.

Although the bark and wood are first killed along the main pathway of movement of the chemical, the bark between the cuts generally dies if the applications have been properly made. This happens especially when the applications are made in the winter

Figure 1. Live oak tree treated in the summer with 2,4–D amine. The bark was removed 3½ years after treatment to show the streaks of killed tissues. The tree was still alive. The letters represent the locations of the cuts.

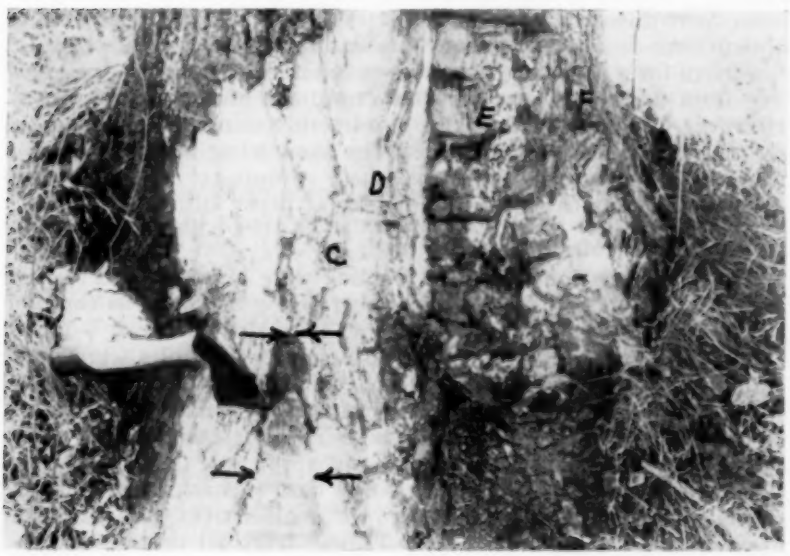


Figure 2. Live oak tree treated in the winter with 2,4–D amine, with the bark removed 9 months later. The top of the tree was dead. The letters represent the locations of the cuts, and the arrows point to some unkilled tissue.

and when the width of uncut bark is not over 2 inches. Evidently, although the main movement of the chemical is vertical, some lateral movement takes place and in sufficient quantity to kill bark. Sometimes the bark between the cuts does not die; this is especially evident when the cuts are too far apart. Basal sprouts may develop from such bands of live bark; also, there is a very good chance that the uncut bark will not die when the applications are made in the summer, as has already been illustrated by the data in Table 1. The tree tops will remain alive, but may eventually break or fall due to rotting; however the sprouts that develop may survive.

Height of cut

In this study, the chemicals were applied to cuts spaced every 6 inches around the stems, with an application rate of 2 ml. per cut. Although the amines and esters of both 2,4–D and 2,4,5–T were used, the kills were somewhat erratic and not sufficient to indicate any specific relationship between height of cut and specific chemical. Considering all treatments together for each height studied (50 trees for each percentage kill listed), the percentage kill decreased as the cuts were made farther from the ground. The average plant kills were as follows: 0 inch, 48%; 6 inches, 38%; 12 inches, 16%; 24 inches, 18%; 36 inches, 16%; 48 inches, 12%. It is evident that kills were highest when the applications were made near the ground line. The significance of these figures must be viewed in light of the fact that the dosage applied decreased upward, due to tapering of the stem. It is significant and not surprising that some of the trees died that were treated as high as 4 feet above the ground. Considering the movement downward as shown in Figures 1 and 2, if no serious obstructions are present below the point of application, the chemical can move for a considerable distance. Some of these trees developed live stem and basal sprouts that eventually died (after 5 years). However, considering that the movement downward is somewhat erratic, it is evident that applications made close to the ground—which is, also, close to the place where sprouts are apt to develop—are most likely to give a high degree of plant kill.

Depth of application

Although tests conducted on live oak were quite limited (4 trees for each treatment), the results appear to be the same as for blue oak (6). Holes one inch in diameter were drilled every 6 inches around the trunk of live oak trees. Some of the holes were made just through the bark (¾ inch deep), while others were drilled well into the wood (2 inches deep). Applications were made in February, the time of the year when this species is most sensitive, as may be judged from Table 4. 2,4–D amine was applied at the rate of 2 ml. per opening. A top kill of one out of 4 trees was achieved when the chemical was placed ¾ inch deep, while all 4 trees died when the applications were 2 inches deep. These trees all developed basal sprouts, some of which died; however, some are still alive, indicating that lateral diffusion of 2,4–D in the wood was limited, especially prior to the formation of the sprouts. The same dosage of chemical

applied to continuous cuts not only killed the tops but prevented sprouting.

Effect of chemical

Data in Table 3 indicate the effect of 2,4–D, 2,4,5–T and MCPA on top and plant kill of live oak. Some data on 2–(2,4,5–TP) are, also, shown in Table 2. There appears to be no real large difference in the effectiveness of 2,4–D and 2,4,5–T or between amines and esters; however, 2,4–D amine appears to be generally the most effective chemical and the same thing appears to be true in Table 2. MCPA appears to be the least effective of the chemicals studied, but the results do suggest that this chemical could be used to kill live oak with the proper dosage; however, a question of economy is involved.

Table 3. Effect of different chemicals on the kill of live oak, 5 years after treatment. Cuts were spaced 6 inches apart.

Chemical	Dosage per cut					
	1 ml.		2 ml.		4 ml.	
	Top kill %	Plant kill %	Top kill %	Plant kill %	Top kill %	Plant kill %
2,4–D amine	10	0	50	40	90	80
2,4–D ester	10	0	20	20	60	50
2,4,5–T amine	10	10	40	30	70	70
2,4,5–T ester	0	0	20	20	70	60
MCPA amine	0	0	10	10	50	40

A series of tests with 3–(*p*–chlorophenyl)–1,1–dimethyl urea (monuron) and 3–amino–1,2,4–triazole applied to cuts were completely negative. One-half gram of actual chemical was applied for each inch of stem diameter. About 4 years after application, the cuts were almost completely healed over and no foliage symptoms evident; likewise, no foliage symptoms had been noted at any time.

Seasonal differences in sensitivity of live oak

Data in Table 4 indicate that marked differences in sensitivity to 2,4–D and 2,4,5–T exist at different times of the year. Top kill

Table 4. Effect of season of application on the top and plant kill of interior live oak treated with the amines of 2,4–D and 2,4,5–T, applied to spaced cuts.

Date of treatment	2,4,5–T amine		2,4–D amine			
	1 ml./cut		1 ml./cut		2 ml./cut	
	Top kill %	Plant kill %	Top kill %	Plant kill %	Top kill %	Plant kill %
August 1951	10	0	10	0	50	40
October 1951	10	0	60	40	70	50
November 1951	60	30	90	70	100	80
December 1951	100	40	90	70	100	80
February 1952	80	40	100	80	100	100
March 1952	50	40	80	40	100	70
June 1952	20	0	30	10	60	20
July 1952	5	5	30	15	40	20

was higher from November through March than it was during the summer and early fall. Field experience by ranchers, farm advisors, and others have consistently and emphatically verified these observations. Seasonal changes in sensitivity appear to be similar with the two chemicals but the actual kills obtained with 2,4–D appear to be slightly higher than for 2,4,5–T.

With respect to plant kill, the kills are lower than for top kill, but the same seasonal trends are evident. It is apparent from the data that plant kill with 2,4,5–T was less than with 2,4–D; in other words, there appeared to be a greater tendency of the treated trees to sprout. An interesting aspect of treatment of trees at different seasons of the year was the interval of time after treatment before signs of leaf kill were evident. Trees treated in April had dead leaves within 1 or 2 months, while trees treated in the late summer and later did not show appreciable leaf-kill until growth started in the spring.

Fate of top-killed trees and sprouts of live oak

A study was made of 75 trees treated in the summer of 1951 in which the tops were killed with 2,4–D and 2,4,5–T, but which developed basal sprouts. The purpose was to note when the tops died, when the trees developed sprouts, and to record the death of the sprouts. Data from these studies are presented in Table 5.

Table 5. Percentages of top kill and sprouting of live oak trees. All applications of 2,4–D and 2,4,5–T were made in August and September 1951.

Observation	Years after treatment			
	1	2	3	5
Top kill	67	86	91	100
Plants with sprouts	33	64	65	47
Time of sprouting	33	37	23	9
Death of sprouts (total)	0	6	28	53

Trees (top kill) continued to die throughout the study period of 5 years. Since the major percentage died within 3 years after treatment, it is not anticipated that an appreciable proportion will die in future years. The increase in top kill was due to several causes including falling over from root injury or breaking off due to rotting; however, most of the tops died while the trees were still standing.

Trees continued to initiate sprouts over the 5-year study period, most of which took place within 3 years after treatment. Because many of the trees that developed sprouts later had these sprouts die, at no time did all of the trees have live sprouts. More trees had live sprouts 3 years after treatment than at any other time. By 5 years after treatment, less than one-half of the trees that had developed sprouts, still had live sprouts. This study does not consider "old" sprouts which were present at the time of the initial treatment; some, but usually not all, of which died as a result of treating the trees. The death of both new and old sprouts is considered as

being due to the 2,4–D or 2,4,5–T in the wood being drawn by transpiratory pull into the sprouts. Preliminary bio-assay tests indicate that the bark and wood (near, but below the point of application) of the treated trees contained as much as 40 ppm 2,4–D 5 years after treatment. The concentration of 2,4–D between cuts was 1 ppm, while a sprout in the process of dying contained 0.02 ppm of extractable 2,4–D. The method being used is based upon the reaction of cotton seedlings to a series of dilutions of purified extracts and compared with known dosages of 2,4–D.

Some trees were treated in February 1952 with 2,4,5–T amine, with the chemical applied to cuts spaced every 6 inches around the trunks. The results were sufficiently striking to be worthy of presentation (Table 6). The data were recorded at different intervals

Table 6. Effect of 2,4,5–T amine on the percentages of top kill and plant kill of interior live oak. Applications of 1 ml. per cut were made to cuts spaced 6 inches apart in February 1952.

Observation	Years after treatment		
	1½	2½	5
Top kill	77	77	85
Plant kill	19	23	70
Fallen trees	0	4	54

following treatment. Results from this study indicate that most of the top kill took place within the first 2½ years after treatment, but that there was a marked increase in plant kill between 2½ and 5 years after treatment. This indicates that many of the trees that had dead tops, had at some time, live sprouts. Some 2,4,5–T was still present in the wood 5 years after treatment, as indicated by some bio-assay tests. Over one-half of the trees and groups of trees (clumps) had fallen within 5 years after treatment.

Effect of spacing of cuts on black oak and madrone

Experiments on black oak and madrone consisted of making comparisons in kill between different chemicals applied to spaced cuts and to continuous cuts. Data from these studies are presented in Table 7. Treatments applied in March and November 1953 resulted in a high percentage of kill for both methods of application. There appeared to be little difference between 2,4–D and 2,4,5–T, although there was some sprouting of the madrones treated with the latter chemical. Top kill and plant kill were the same at the time the data were recorded, so only the latter data are presented.

The results with 2–(2,4,5–TP) were interesting, although the amine and ester forms were not used at the same time. The ester of 2–(2,4,5–TP) proved to be poor, while the amine form appeared to be quite effective on both black oak and on madrone. The poorest kills were obtained by an application in July 1954; these results were anticipated on the basis of the seasonal cycle of sensitivity of live oak reported in Table 4. All of the trees were cut with a chain saw in the summer of 1956 and no further readings will be possible.

Table 7. Plant kill of black oak and madrone by chemicals applied to spaced cuts and to continuous cuts. The quantity of chemical used was 1 ml. per inch of stem diameter.

Chemical	Black oak		Madrone	
	Spaced cuts	Continuous cuts	Spaced cuts	Continuous cuts
	Plant kill %	Plant kill %	Plant kill %	Plant kill %
		March 1953		
2,4–D amine	100	100	100	100
2,4,5–T amine	80	100	80	100
2–(2,4,5–TP) ester	0	0	20	40
		November 1953		
2,4–D amine	90	100	100	100
2,4,5–T amine	90	100	100	100
2–(2,4,5–TP) amine	100	100	100	100
		July 1954		
2,4–D amine	100	100	80	80
2,4,5–T amine	100	100	40	60
2–(2,4–DP) amine	20	40	50	50
2–(2,4,5–TP) amine	100	100	80	100

Discussions and Conclusions

Application of phenoxy herbicide concentrates to cuts in the trunks of trees has proven to be generally effective against a wide variety of species in California. Results presented in the present paper are for those obtained on interior live oak, black oak, and madrone. Amine salts of 2,4–D, 2,4,5–T, and 2–(2,4,5–TP) all seem to be relatively effective. The amines appear to be superior to the esters, although an increase in dosage can overcome this difference. Because of cost, the 2,4–D amine is the favored chemical. Similar conclusions were drawn from studies conducted on blue oak (6); it is, also, the most effective chemical on digger pine (2, 8).

The type of application made with the Cornell tool is similar in principle to those made in the present paper. By the use of this tool, Goddard (4) obtained some excellent kills on all species with an ester of 2,4,5–T in diesel oil. The best kills were obtained using 80 pounds of acid equivalent per 100 gallons of diesel oil, which was the highest concentration used. Darrow (1) reported that live oak *(Quercus virginiana)* could be killed with the esters of 2,4–D or 2,4,5–T applied to notches or frills in the trunks during the dormant season.

Spacing of the cuts was of appreciable importance, especially in relation to consistency of kill. Close spacing was superior to wide spacing, with continuous cuts being best, especially with summer treatments. The summer periods in California are almost rain-free, which reduces the moisture content of the sapwood. Tension in the xylem is considerable and to the extent that after being cut, a hissing sound is often heard due to air being drawn back into the wood. The chemical is drawn up and down in the wood, but lateral movement is limited. The channels of movement can be observed later by stripping away the bark and noting the channels of markedly discolored wood. Good kills can only be obtained by placing the cuts

quite close together and by using a rather high dosage. During the winter period, tension in the xylem appears to be less and the wood moist. Treatment during this period results in a much broader band of tissues killed than occurs during the summer. Another factor that likely influences relative effectiveness of winter and summer treatments with 2,4–D, is the slower rate of breakdown of the chemical during the winter period, such as has been reported by Weintraub et al. (9).

It was originally thought that the chemicals applied to the xylem would be moved to the leaves and could be translocated to the roots through the bark; this suggested the necessity of leaving strips of uncut bark to make this type of movement possible. Evidently, this type of movement does not occur (with 2,4–D and 2,4,5–T), at least to any appreciable extent. Studies with radioactive 2,4–D* on live oak indicate that this compound translocates for only a short distance in the bark (7). The same type of evidence has been obtained by spraying branch tips of live oak with unlabeled 2,4–D and observing the kill on the unsprayed portion for 2 or more years (7). Evidently, the wood is the primary tissue in which the chemicals are moved after being applied to the cuts. Shallow applications probably resulted in most of the 2,4–D being broken down in the bark and in and near the cambium. Hay (5) arrived at a similar conclusion, working with marabu; however, he did not mention the possibility that the nonphysiologic "bound" 2,4–D might become released eventually and become "free" 2,4–D again. That free 2,4–D and 2,4,5–T may persist for a long time in some tissues was demonstrated by the wood of live oak still containing these chemicals, even 5 years after treatment.

Top kill occurred rapidly, especially when the applications were made in the spring. When applications were made in the fall or winter, no effect was evident until growth started in the spring. Sometimes the tops continued to die over a period of from 3 to 5 years. Although the tops were killed, frequently this did not mean the trees were entirely killed, since sprouts often formed around the bases of the trees. Even though sprouts developed in many cases, many of these eventually died. In one experiment with 2,4,5–T amine, a very high mortality of sprouts took place between 3 and 5 years after treatment. The reasons for this delayed kill of sprouts seems likely to have been due to the 2,4,5–T still present in the wood being drawn into the sprouts in the process of transpiration. Other factors have undoubtedly contributed to the kill, including root injury, fungi, and browsing by deer. Delayed kills have previously been reported for live oak sprayed in the fall of the year with 2,4–D amine (3). Such kills do not occur when 2,4–D amine is applied during the active growing season. It appears likely that the "bound" 2,4–D is eventually released, resulting in the death of the plants. That a 2,4–D "binding" chemical develops in live oak after shoot growth ceases is certainly suggested by the results of Leonard and Crafts (7) and Emrick and Leonard (3).

When sprouts are present near the bases of the trees at the time

of treatment, some of the sprouts around each tree are killed, but seldom all of them. It now appears that the best program to follow is to burn the site between 3 and 5 years after treatment; this will open the area enough so that ground spray equipment might be used for controlling the regrowth—much of which may be species other than live oak, such as poison oak and evergreen shrubs.

SUMMARY

1. The effect of 2,4–D, 2,4,5–T, 2–(2,4–DP), and 2–(2,4,5–TP) concentrates applied to cuts in stems of interior live oak, black oak, and madrone are reported in the present study. The relationship of spacing of the cuts, dosage, seasonal changes in sensitivity, and other factors were studied.

2. Most dependable kills were obtained when all the bark was severed around the trunks. However, good kills could be obtained during the late fall and winter with the cuts spaced every 6 inches around the tree (a cut for each 6 inches of circumference).

3. Best kills appear to be obtained when the chemicals are placed in the sapwood and when the cuts are made near the base of the trees. The latter item appears to be especially important for interior live oak and of lesser importance for black oak and madrone.

4. Amine formulations were somewhat superior to ester formulations; however, the advantage of the amines could be overcome by increasing the dosage with the esters.

5. Although 2,4–D appeared to be generally the most satisfactory of the phenoxy herbicides studied, good results were obtained with 2,4,5–T and 2–(2,4,5–TP) amines. The amines of 2–(2,4–DP) and MCPA were less effective. Monuron and ATA appeared to be without any effect when applied to cuts in live oak.

6. A considerable delay in sprout kill was evident in some cases. Considering all treatments, over one-half of the trees with dead tops that had basal sprouts, eventually died. The delay in death of the sprouts sometimes took from 3 to 5 years and was probably due to the free 2,4–D and 2,4,5–T present in the wood being drawn into the shoots by transpiratory pull.

7. The trees appear most sensitive during the late fall and winter to the cut surface method, and least sensitive during the summer. By increasing the dosage and applying the chemical to continuous cuts, the method can be reasonably effective at all seasons.

ACKNOWLEDGMENT

The author desires to express his appreciation to L. J. Gamble and John Allen for making their ranches available for these studies, and to L. Farrell, C. Hamilton and A. L. Johnston for their help in making the applications.

LITERATURE CITED

1. DARROW, ROBERT A. Chemical control of live oak and shin oak in the Edwards Plateau. Proc. Southern Weed Conf. 8:269–277. 1955.

2. EMRICK, WALTER E. An easy way to kill your bull (digger) pines. Univ. California Ext. Service Leaflet (Madera County) pp. 1–9. 1953.
3. ———— and LEONARD, O. A. Delayed kill of interior live oak by fall treatment with 2,4–D and 2,4,5–T. Jour. Range Management 7:75–76. 1954.
4. GODDARD, RAY E. Killing small undesirable hardwoods by the use of the Cornell Tool. Down to Earth 10(2):5. 1954.
5. HAY, J. R. Translocation of herbicides in marabu. I. Translocation of 2,4,5–trichlorophenoxyacetic acid following application to the bark or to cut-surfaces of stumps. Weeds 4:218–226. 1956.
6. LEONARD, OLIVER A. Effect on blue oak *(Quercus douglasii)* of 2,4–D and 2,4,5–T concentrates applied to cuts in trunks. Jour. Range Management 9:15–19. 1956.
7. ———— and Crafts, Alden S. Translocation of herbicides. III. Uptake and distribution of radioactive 2,4–D by brush species. Hilgardia 26(6): 366–415. 1956.
8. ———— and HARVEY, W. A. Chemical control of woody plants in California. Calif. Agr. Expt. Sta. Bul. 755. 1956.
9. WEINTRAUB, R. L., REINHART, J. H., SCHERFF, R. A., and SCHISLER, L. C. Metabolism of 2,4–dichlorophenoxyacetic acid. 3. Metabolism and persistence in dormant plant tissue. Plant Physiol. 29:303–304. 1954.

Amino Triazole Salts and Amino Triazole–5–C^{14} Studies on Pigment Production in Cotton

C. S. Miller and Wayne C. Hall[1]

The influence of 3–amino–1,2,4–triazole (ATA) and eight of its salts or derivatives on defoliation and secondary growth in cotton, the straight growth and respiration of *Avena* sections, and the respiration of cotton leaf discs were reported in a previous paper (6).

It was found in earlier work (2) that ATA caused chlorophyll destruction and inhibited chlorophyll synthesis in the cotton plant. Cotton plants in the field often develop red coloration, particularly in the new growth, following treatment with ATA. This suggested that ATA also affects the anthocyanins. Translocation experiments (2) in the greenhouse indicated that ATA was readily absorbed by the roots and aerial organs of the cotton plant; indirect evidence suggested that the compound was mainly transported upward.

The present work was undertaken to study in some detail the effects of ATA and the acetate, phosphate, and sodium salts of ATA on the chloroplast and anthocyanin pigments of cotton leaves. By the use of radioactive ATA, direct evidence was obtained on the absorption and movement of ATA in the cotton plant and its influence on pigment synthesis.

Methods and Materials

Pigment studies. Cotton plants were grown in fertile soil in 3-gallon jars in the greenhouse. When most of the bolls were mature, aqueous solutions of 1500 ppm concentrations (ATA equivalent basis) of ATA and its acetate, phosphate, and sodium salts were prepared, and plants were sprayed to run off. The low concentrations (1500 ppm) of ATA and the salts were employed to allow some regrowth in the treated plants to take place. An unsprayed lot was used for controls. Seven days after application all undefoliated original foliage of the treated and control plants was removed by hand.

Three weeks after application, when the new growth of the treated plants exhibited various degrees of chlorosis, the regrowth was collected for pigment determinations. The methods used for the extraction, separation, and identification of chlorophylls *a* and *b*, the xanthophylls, and carotenes were modified slightly from those described by Loomis and Shull (5) and Highkin (3). Preliminary experiments with untreated cotton leaves had insured that the methods were reproducible and suitable for use for the chloroplast pigments of cotton. Equal aqueous dilutions of the saponified chlorophyllides of chlorophylls *a* and *b* were made for comparison of optical densities at 6600 Å using a Beckman model DU spectrophotometer.

[1]Research fellow and Professor, Department of Plant Physiology and Pathology, Texas A. and M. College System, College Station, Texas.

Paper chromatographic chloroplast pigment separation was also accomplished by the technique reported by Lind et al. (4). The plastid pigments were extracted from cotton leaves with acetone in a Waring blendor and transferred to petroleum ether. One-tenth ml. of the petroleum ether solution was placed at the origin of a 23 by 23 cm. square of Whatman No. 1 filter paper previously washed with petroleum ether and dried. The filter paper was stapled together to form a cylinder and placed in a tightly covered widemouth gallon jar containing 100 ml. of developing solvent. In the first dimension petroleum ether followed by petroleum ether containing 1% N–propanol were used as solvents. The petroleum ether moved the carotenes far ahead of the other pigments, and development was stopped when the solvent was 20 cm. from the bottom of the paper. One volume percent N–propanol in petroleum ether separated the remaining pigments, and development was stopped when the solvent had moved 20 cm. from the bottom of the paper. The pigments were further separated by developing in the second dimension with 25 volume percent chloroform in petroleum ether. The development was stopped when the solvent had moved up about 16 cm. The paper was air dried after development in each of the successive solvents (4).

Rf values were determined for each treatment after development in petroleum ether, petroleum ether containing 1 percent N–propanol, and petroleum ether containing 25 volume percent chloroform (4).

Anthocyanin pigments from regrowth leaves of ATA-treated and control plants were extracted by a slight modification of the procedure reported by Thimann and Edmondson (11). Regrowth leaves were harvested and shredded slightly before extracting for 3 to 4 hours with occasional stirring with 0.1 N HCl (10 ml. for each gram of fresh tissue). The mixture was then filtered. The filtrate containing the anthocyanin pigments was used for determining their absorption spectra with a Beckman DU spectrophotometer. After the absorption spectra were determined, 0.1 ml. of the filtrate was placed at the origin of a strip of Whatman No. 1 filter paper (3 by 23 cm.) and chromatographed using a butanol-acetic acid-water (40: 10: 50 v/v) solvent method described by Bate-Smith (1).

Radioactive amino triazole studies. Radioactive 3–amino–1,2,4–triazole–5–C^{14}, with a specific activity of one millicurie per millimole, synthesized by Tracer Lab, Inc., was used in the studies.

Cotton plants, four per 3-gallon jar, were started outside the greenhouse and moved inside for the C^{14} studies. The leaves of some of the plants were removed to obtain a five-leaf uniformity on each plant. The lower two leaves were treated with 1500 ppm solution of ATA containing a radioisotope concentration of 3.6×10^6 counts per minute per ml. of treating solution. The solution was applied to the upper surface of the leaves with a small camel-hair brush. At 12, 24, 48, 72, and 168 hours after application, one plant was harvested and pressed in a plant press while drying in an oven at 65° C. for a period of 24 hours. The harvest operation consisted of pulling the entire plant, washing the roots, and subdividing into the stem,

root, and leaves. One of the two treated leaves of each plant was washed thoroughly in distilled water, the other was left unwashed to determine the relative amounts of ATA absorbed and remaining on the leaf surfaces. After drying, the various parts were glued in position on a cardboard sheet and exposed to X-ray film for 13 days; after this period, the film was developed.

In another experiment six jars each containing four greenhouse-grown cotton plants per jar were placed in a plastic chamber two days before treatment with radioactive ATA. The treating solution of 1500 ppm ATA, which had an activity of 3.5×10^6 counts per minute per ml., was applied to the upper surface of the leaves with a small camel-hair brush. One day after treatment the leaves were harvested and the pigments were solvent-extracted and separated (3, 5). The amount of radioactivity associated with each fraction was determined with a Geiger tube of 0.2 mg/cm² window thickness (Micromil, Nuclear-Chicago) attached to a Decade scaler, Nuclear Model 181. Chromatographic pigment separations from plants treated with radioactive ATA were also accomplished by the method described by Strain (9) using petroleum ether and 1 percent N–propanol. After the original leaves were removed, these same plants were then allowed to remain in the chamber in the greenhouse for three weeks to permit regrowth. The regrowth leaves from the same plants were harvested, the pigment separations made, and the radioactivity of the fractions counted as described above.

RESULTS

Chloroplast pigment studies. The optical densities of chlorophyllides *a* and *b* from equal aliquots of extracts of regrowth leaves from untreated cotton plants and those treated with 1500 ppm ATA and the acetate, phosphate, and sodium salts of ATA are presented in Table 1. Compared to the controls, ATA and its salts reduced the relative amounts of both chlorophylls. The optical density measurements confirmed the visual chlorotic appearance of the regrowth leaves; the plants treated with the sodium salt of ATA were clearly the most chlorotic, and the plants treated with ATA and the acetate salt were the least chlorotic.

Chromatograms showing final separation of the chloroplast pigments of the cotton leaves by the two dimensional method of Lind

Table 1. The optical densities of chlorophyllide *a* and *b* solutions, prepared from regrowth leaves of cotton plants treated with 1500 ppm ATA and its salts, as measured in a Beckman model DU spectrophotometer.

Treatment	Optical densities of equal aliquots at 6600Å	
	Chlorophyllide *a*	Chlorophyllide *b*
Non-treated controls	0.64	0.07
ATA	0.42	0.06
Acetate salt of ATA	0.53	0.02
Phosphate salt of ATA	0.30	0.02
Sodium salt of ATA	0.02	0.01

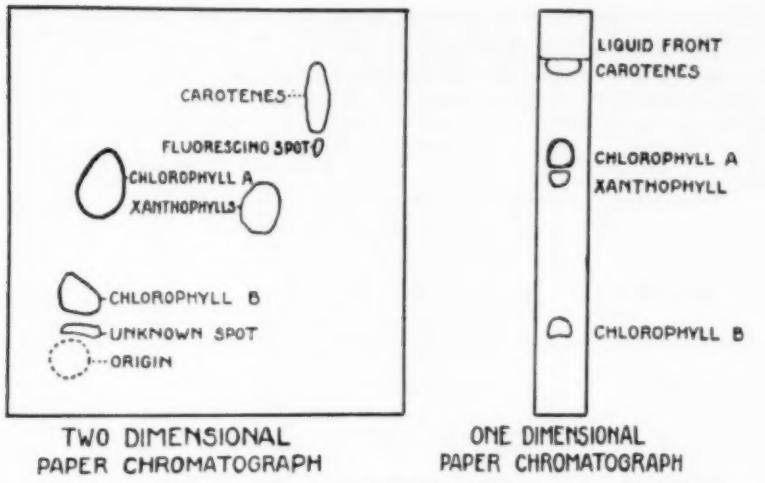


Figure 1. Tracings of paper chromatographic separation of the chloroplast pigments of the cotton leaf. Left—two dimensional separation by method of Lind et al. Right—single dimensional separation with 1% n–propanol in petroleum ether (modified method of Strain).

et al. (4) and the one dimensional method of Strain (9) are shown in Figure 1. The two dimensional separation of pigments by the Lind et al. (4) method resulted in clear, well defined and well separated spots containing the plastid pigments. There were no great differences in Rf values of the pigments from treated regrowth as compared to the normal regrowth leaf pigments, with the possible exception of the chlorophyll *a* fraction from the leaves of plants treated with the sodium salt of ATA and the chlorophyll *b* fraction in solvent 2 (Table 2). Chlorophyll *a* from the plants treated with the sodium salt moved less in petroleum ether on paper than chlorophyll *a* from the controls and more than the normal chlorophyll *a* in petroleum ether containing 1% N–propanol.

The position of chlorophyll *a* from treated leaves on the chromatograms, as indicated by the Rf values, was different from that shown by Lind et al. (4). This was apparently due to the oxidation of the pigment while on paper for a period of several hours. The oxidation of chlorophyll *a* changed its position, after final movement in 25 volume percent chloroform in petroleum ether, to coincide with the position occupied by the ultra violet-fluorescing spot reported by Lind et al. (4); this fluorescing spot was found on chromatograms made from regrowth leaves of normal, untreated cotton (Figure 1). No other ultra violet-fluorescing spot was detected on chromatograms made from regrowth leaves of plants treated with ATA or the salts used.

Although the single dimensional method of Strain (9) resulted in fair separation of pigments from cotton leaves (Figure 1), the chlorophyll *a* spot slightly overlapped that of the xanthophylls. The Strain

Table 2. Comparison of Rf values of plastid pigments from untreated cotton leaves and leaves of plants treated with 1500 ppm ATA or its salts. Solvent 1: petroleum ether. Solvent 2: 1% n-propanol in petroleum ether. Solvent 3: 25 volume per cent chloroform in petroleum ether.

Pigment	Treatment	Rf value		
		Solvent 1	Solvent 2	Solvent 3
Chlorophyll *a*	Untreated control	0.25	0.78	0.93
	ATA	0.22	0.62	0.91
	Acetate salt of ATA	0.23	0.57	0.94
	Phosphate salt of ATA	0.23	0.57	0.94
	Sodium salt of ATA	0.14	0.91	0.95
Chlorophyll *b*	Untreated control	0.14	0.17	0.03
	ATA	0.16	0.00	0.06
	Acetate salt of ATA	0.15	0.00	0.07
	Phosphate salt of ATA	0.16	0.13	0.09
	Sodium salt of ATA	0.13	—	—
Carotenes	Untreated control	0.96	—	0.90
	ATA	0.97	—	0.90
	Acetate salt of ATA	0.96	—	0.91
	Phosphate salt of ATA	0.96	—	0.91
	Sodium salt of ATA	0.96	—	—
Xanthophylls	Untreated controls	—	—	0.63
	ATA	—	—	0.72
	Acetate salt of ATA	—	—	0.70
	Phosphate salt of ATA	—	—	0.80
	Sodium salt of ATA	—	—	—

method was used in the separation of pigments from plants treated with radioactive ATA because of its ease and the speed of separation of the pigments as compared to the method of Lind et al. (4).

Anthocyanin studies. During the separation of pigments from regrowth leaves of treated plants, a red coloration remained in the acetone extract after separation of the acetone-petroleum ether fractions in the first transfer of pigments, whereas the red coloration was absent from the acetone extract of untreated cotton regrowth leaves. The red pigment in the acetone extract of ATA-treated leaves was identified as an anthocyanin by knowledge of its properties and by qualitative tests.

The material extracted from the regrowth leaves was insoluble in ether, but was soluble in water and dilute acid. Dilute HCl converted the colorless glucosidic form of the pigment to the red colored form. The red colored form turned blue when the solution was made basic. The slightly acidic solution became colorless with the addition of a small amount of zinc dust. These tests suggest that the material was an anthocyanin which was colorless in the glucosidic form in the leaves but changed to the red anthocyanidin form when extracted with dilute HCl.

The absorption spectra of the dilute HCl extracts from ATA-treated and control regrowth leaves are illustrated in Figure 2. Comparison of the two curves indicate that there is an increased production of anthocyanin following the application of ATA to cotton plants. Although there was approximately twice as much anthocyanin in the regrowth leaves from ATA-treated plants as in normal leaves, the inflections of the curves indicates little alteration

in the properties of the anthocyanins due to treatment with ATA. Further evidence against a change in chemical composition of anthocyanin was shown by identical Rf values of 0.28 found when the anthocyanin fractions from treated and normal regrowth leaves were chromatographed on paper using the butanol–acetic acid–water mixture as the mobile phase (1).

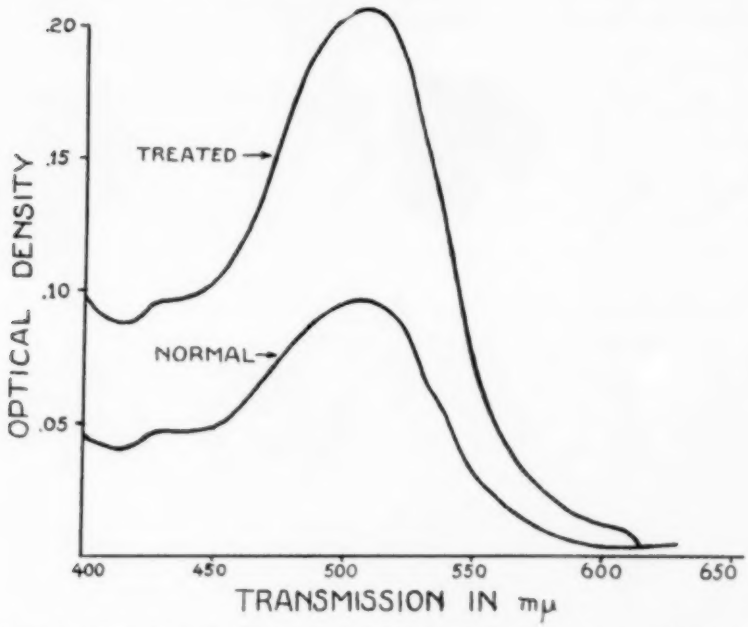


Figure 2. Absorption spectra of anthocyanidins extracted from untreated regrowth leaves and regrowth leaves of cotton plants treated with 1500 ppm ATA. Points on the curves were determined at units of 10 millimicrons with a Beckman DU spectrophotometer.

Radioactive studies. Radioautographs, shown in Figure 3, of the various parts of cotton plants treated with radioactive ATA indicated translocation of ATA mainly to the younger tissues of the shoot. Much of the detail of the original negatives was lost in making a composite print. The single digit numbers from 1 to 5 indicate the original position of the leaves on the stem and correspond to the second digit designating the detached leaves. The older, untreated, fully expanded leaves (leaves 3 and 4) which were intact at time of treatment, contained very little of the radioactivity. The light appearance of the stems and veins was believed to be due principally to the thickness of tissue which blocked the weak C^{14} radiation. Radioactivity was found in the terminal portions of the plant by the end of the first day (Figure 3A) and increased in the young growth up to seven days (Figure 3B and 3C). It is conceivable that under normal field conditions of higher transpiration that a

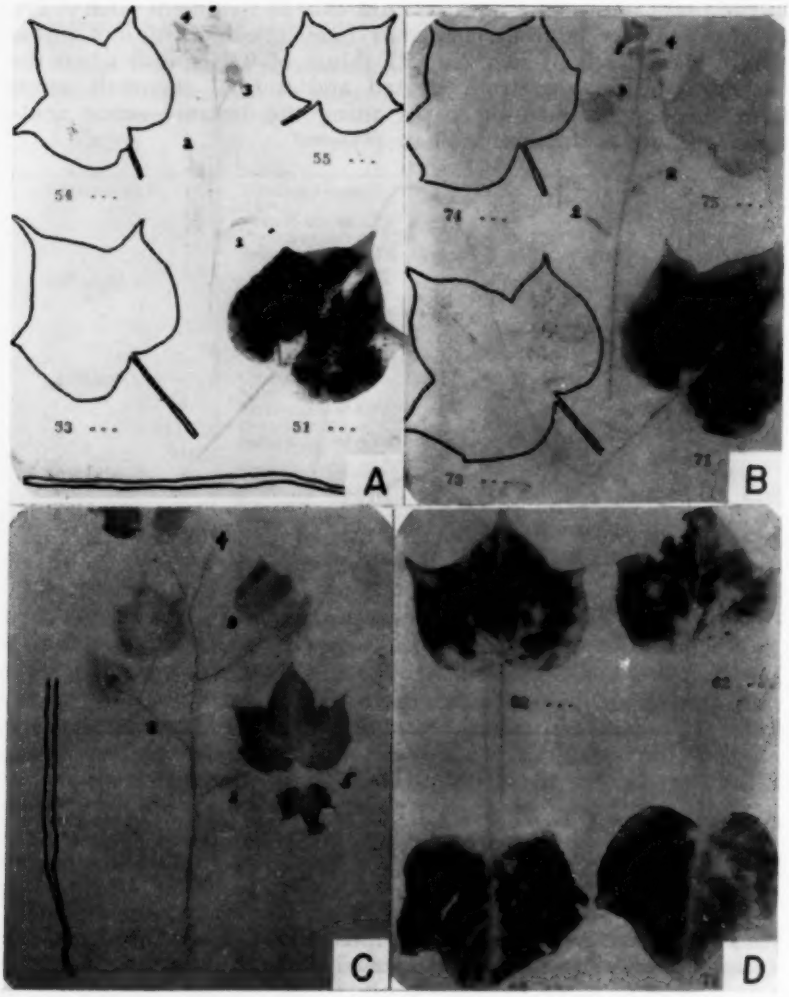


Figure 3. Radioautograms of parts of cotton plants after application of radioactive ATA to the two lowermost leaves (leaves 1 and 2). Single digit numbers indicate the original leaf positions on the stem at time of treatment and corresponds to the leaf number (second digit of the two digit numbers). A. After 1 day. B. After 3 days. C. After 7 days. D. Washed treated leaves.

greater amount of ATA would be translocated in a shorter time. The high radioactivity of treated leaves that were thoroughly washed (Figure 3D) showed that considerable ATA was absorbed in a relatively short time after application, although the washings also contained activity.

The radioactivities of pigment-containing extracts from the original leaves harvested one day after treatment with radioactive ATA

are given in Table 3. The original acetone extract containing all of the plastid pigments accounted for about one-tenth of the radioactivity applied to the leaves. The majority of the activity of the original extract remained in the acetone and water washings after transfer of the pigments to petroleum ether, indicating that the activity was extracted with water or was associated primarily with constituents of the leaves other than the pigments. The petroleum ether extract retained only about one-sixth of the original activity that was extracted by acetone.

Table 3. Radioactivities of pigment-bearing extracts from the original cotton leaves and the regrowth leaves produced after 3 weeks in the greenhouse.

Extract	Counts per minute	
	Per 0.5 ml.	Total
Original leaves		
Original acetone extract	314	78,500
Acetone and H_2O after transfer to petroleum ether	221	55,250
Petroleum ether	56	14,000
0.1 gm. of dried residue	664	——
Regrowth leaves		
Original acetone extract	—	606
Acetone and H_2O after transfer to petroleum ether	—	399
Chlorophyll *a*	—	86
Carotene	—	31
Chlorophyll *b* and xanthophyll	—	109
HCl (anthocyanins)	—	156
Background count	—	15

The activities of 0.5 ml. aliquots of the other pigment fractions were too low to count after separation. The total activity remaining in the leaf residue after extraction could not be calculated due to a lack of a thickness correction factor. Oxidation of the tissue to carbon dioxide and conversion to barium carbonate was not attempted in the present experiments. However, since only about one-tenth of the activity applied to the leaves was removed in the acetone extract, it was assumed that the balance of the activity remained in the residue after extraction, minus what was transported to apical plant parts.

Pure ATA is insoluble in acetone. The activity of the acetone extract, therefore, can be accounted in only the following ways: some of the ATA either had been metabolized or was altered, was in a combined form, or there was sufficient water from the leaf tissue in the acetone extract for ATA to be removed.

Table 3 shows the radioactivities of the pigment-bearing extracts from the regrowth leaves harvested three weeks after treatment. The total activity of the 6 grams of regrowth leaves was small, probably because of impaired translocation in the high humidity of the plastic chamber. The major portion of the activity extracted by the acetone remained in the acetone after transfer of the pigments to petroleum ether. Only a small portion of the activity remained associated with the different pigment fractions after their separation in the different solvents. The anthocyanin-bearing HCl extract of a portion of the

regrowth leaves contained only about one-third of the activity found in the acetone extract.

One-tenth ml. aliquots of the extracts from both the original and regrowth leaves were chromatographed in one dimension on filter paper (9). Radioactivities associated with the pigment spots were too low to count. It was found that a small amount of the original radioactive ATA treating solution chromatographed with the same solvent (9) did not move from the origin.

DISCUSSION

Chromatographic separation of the plastid pigments from cotton leaves showed that the total concentration of chlorophylls *a* and *b*, carotenes, and xanthophylls was reduced by ATA treatment. The reduction in the carotenes and xanthophylls, although not determined colorimetrically, was apparent visually on the paper chromatograms. It was also apparent from both the colorimetric measurements and from chromatograms that chlorophyll *a* content was reduced comparatively less by ATA than the other chloroplast pigments.

An apparent oxidation of the chlorophylls prior to or during the chromatographic separation on paper with petroleum ether was noted. Prior impregnation of the paper with sucrose alleviated the oxidation but did not prevent it. The oxidation is characterized by loss of fluorescence under ultra violet light. It was after movement of the chlorophylls in petroleum ether that they lost their characteristic red fluorescence. The second dimensional movement, in which chloroform is used, restored a portion of the fluorescence to chlorophyll *a* as indicated by the fluorescing spot which separated distinctly from the slightly oxidized chlorophyll *a* spot. The fluorescing spot in the position described by Lind et al. (4) was not found on the chromatograms made with extracts from regrowth leaves of ATA-treated plants, but oxidation of chlorophyll *a* changed its position, after movement in the second dimension, to coincide with the red fluorescing spot.

It is possible that a structural change may result from the addition of ATA to a keto or other group on the chlorophyll molecule. The radio-chemical studies, however, showed that the pigment spots on chromatograms had only negligible activity.

In the pigment separation of regrowth leaves from ATA-treated plants, the red color remaining in the acetone layer after transfer to petroleum ether was identified as an anthocyanin. There was no apparent red coloration in the separated acetone extract from normal regrowth, nor was there a visible color in the regrowth of treated plants in the greenhouse. The anthocyanins extracted with HCl from chlorotic regrowth leaves was assumed to be in the colorless glucosidic form, which was converted to the red anthocyanidin by the dilute acid extraction. The anthocyanins increased at least two-fold in plants treated with ATA, but were unaltered by treatment as identical Rf values of 0.28 were obtained for extracts from control and treated leaves when chromatographed, and both turned blue

when exposed to ammonia fumes. It should be pointed out that the normal regrowth leaves were much larger and in a different stage of physiological maturity than the smaller, inhibited regrowth leaves from treated plants. This may also have had some influence on the difference in anthrocyanin content.

The over-all effect of ATA appears to inhibit the formation of the plastid pigments but to increase the anthocyanins. The effects of ATA on sugar accumulation (2) and possible complex formation with glucose no doubt are involved in the increased production of the anthocyanins.

The radioautograms indicated fairly rapid absorption and translocation of ATA after application to the basal cotton leaves. The uniformity of distribution of the activity in meristems and young tissues of the shoot suggested that ATA was associated with or had become a part of the constituents of new tissue. The extremely low activity in the roots showed clearly that under the conditions of the experiment there was little basipetal movement of ATA within one week after application to the lower leaves. This was also the conclusion of previous work (2) in which conventional methods were used to study translocation of ATA in cotton. Work with other species, however, indicates considerable movement of ATA to the roots or underground structures (8).

It is apparent that there are two types of chlorosis caused by ATA. One is the destruction of chlorophyll occurring shortly after the application of high rates, particularly under conditions of high light and temperature. The second, investigated in the present study, is a systemic type, which results from sub-lethal doses. This chlorosis is a manifestation of inhibited synthesis of both the chlorophylls and the carotenoids.

In earlier work (2) it was suggested that ATA might be substituting as a pyrrole in the formation of the porphyrin structure of chlorophyll. From their studies, Sund et al. (10) concluded that ATA may affect the physiological processes of a plant in three different ways: (1) It may act as a precursor in the formation of some porphyrin similar to chlorophyll but unable to carry on the functions of chlorophyll. (2) It may complex some metal(s) required for the development of chlorophyll; or complexing with them form a precursor in chlorophyll synthesis. (3) It may upset some oxidation-reduction reactions within the plant. From the present work with C^{14}-labeled ATA, the posibility that ATA is acting as a precursor in the formation of an abnormal porphyrin appears to be remote. Also based on the previous study (2), the results suggest, although not conclusively, that inhibition of chlorophyll synthesis is not entirely due to its complexing of a necessary metal. As pointed out by Rogers (7), ATA may inhibit plastid development. This may explain the inhibition of carotenoid synthesis as well as chlorophyll synthesis by ATA.

Activity in the acetone soluble fraction indicated possible complex formation with organic compounds. It is apparent that a detailed study of possible complex formation with sugars, proteins, and

nucleic acids would aid in understanding the role of ATA in the fundamental enzymatic reactions involved in growth and pigment synthesis. It has already been established that ATA affects oxidation-reduction reactions such as respiration (2). Undoubtedly, other enzyme systems are also affected by ATA.

SUMMARY

1. The chloroplast pigments of cotton regrowth leaves from ATA-treated plants were greatly reduced from normal as shown by paper chromatography, visually, and from the optical densities of the pigment extracts. The chlorophyll *a* content of regrowth leaves was reduced the most in plants treated with the sodium salt of ATA and least when the acetate salt of ATA was used. Two dimensional chromatography showed no great qualitative differences in the plastid pigments from ATA-treated and control leaves.

2. There was an approximate two-fold increase in the anthocyanin content of regrowth leaves following treatment with ATA and ATA salts. Rf values and absorption spectra indicated that the chemical composition of the anthocyanin fraction was unaltered by ATA treatment.

3. Radioautographs showed primarily an acropetal movement of ATA within 24 hours after application to basal leaves.

4. Extremely low C^{14} activity from labeled ATA in the separated pigment fractions from regrowth leaves of treated plants indicated little likelihood that ATA was entering directly into the structure of the pigments. The presence of ATA in the acetone extract suggests that ATA was structurally altered or was combining or complexing with other plant constituents.

ACKNOWLEDGMENTS

The authors are indebted to the American Chemical Paint Company, Ambler, Pennsylvania, for supplying the ATA, ATA salts, and radioactive ATA used in the studies. Thanks are due Dr. James L. Liverman, Texas Agricultural Experiment Station, College Station, Texas, for technical assistance in making the radioactivity measurements and to Anderson, Clayton and Company, Houston, Texas, for providing a fellowship for the senior author.

LITERATURE CITED

1. BATE-SMITH, E. C. Paper chromatography of anthocyanins and related substances in petal extract. Nature 161:835–838. 1948.
2. HALL, W. C., JOHNSON, S. P., and LEINWEBER, C. L. Amino triazole, a new abscission chemical and growth inhibitor. Texas Agri. Exp. Sta. Bul. 789. 1954.
3. HIGHKIN, H. R. Chlorophyll studies in barley. Plant Physiol. 25:294–306. 1950.
4. LIND, E. F., LANE, H. C., and GLEASON, L. S. Partial separation of the plastid pigments by paper chromatography. Plant Physiol. 28:325–328. 1953.
5. LOOMIS, W. E., and SHULL, C. A. Methods in plant physiology. McGraw-Hill Book Company. 1937.

6. MILLER, C. S., and HALL, W. C. The effects of amino triazole and amino triazole salts and derivatives on cotton defoliation, regrowth inhibition, and respiration. Weeds 5:218–226. 1957.
7. ROGERS, B. J. Action of 3–amino–1,2,4–triazole in plants. Paper given at AIBS Meetings, Storrs, Conn. 1956. Plant Physiol. 31 (Supplement): 21. 1956.
8. ———. Translocation and fate of amino triazole in plants. Weeds 5:5–11. 1957.
9. Strain, H. H. Paper chromatography of chloroplast pigments. Jour. Phy. Chem. 57:638–640. 1953.
10. SUND, K. A., GORDON, F. M., and WALWORTH, B. L. Agricultural applications and soil residue studies of 3–amino–1,2,4–triazole. Mimeo. 18 pp. American Cyanamid Co., Stamford, Connecticut. 1955.
11. THIMANN, K. V., and EDMONDSON, Y. H. The biogenesis of the anthocyanins. I. General nutritional conditions leading to anthocyanin formation. Arch. Biochem. 22:33–53. 1949.

Some Effects of 2,2–Dichloropropionic Acid on Soil Microorganisms[1]

A. D. Worsham and Joel Giddens[2]

The increasing use of dalapon (sodium salt of 2,2–dichloropropionic acid) by farmers and agricultural workers has stimulated interest in its effect upon the soil microflora and soil microbiological processes. Thiegs (7) and Holstun and Loomis (3) concluded that dalapon is broken down by an undertermined fraction of the soil microbial population. Magee and Colmer (4) reported that dalapon at rates higher than those used in field applications, was toxic, as measured by manometric methods, to certain species of Azotobacter. Smith, Dawson, and Wenzel (6) reported the effects of several other herbicides on soil microorganisms under laboratory conditions.

Since information regarding the effect of dalapon on soil microorganisms is meager, the experiment reported in this paper was set up to determine if relatively large dosages of dalapon would have a harmful or beneficial effect upon the numbers and some of the functions of the broad groups of soil microorganisms.

Materials and Methods

Sixteen 2-gallon glazed stoneware pots were each filled with 20 pounds of Cecil sandy loam soil which had been partially air dried and passed through a 4-mesh screen. One hundred pounds per acre each of N as ammonium sulfate, P_2O_5 as super phosphate, and K_2O as muriate of potash were added and uniformly mixed with the soil in each pot. The fertilizer was applied on a weight of soil basis assuming 2,000,000 pounds as an acre. Tap water was added to each pot in portions until a total of 1500 ml. had been added. The dalapon,[3] at rates of 17, 34, and 68 pounds active ingredient per acre on a surface area basis, was sprinkled on the soil in 250 ml. water. Another 250 ml. of water was added to each pot after the dalapon treatment bringing the soil to approximately field capacity. The pots were watered as needed throughout the experiment with distilled water. Four replications of each treatment plus control pots which received no dalapon were set up in a completely randomized design in the greenhouse on June 21, 1956. The greenhouse temperature varied from approximately 80° F. at night to daytime temperatures of 95° F. with a few days reaching 103° F.

To determine the effect of the chemical on the soil microbial population of bacteria, actinomycetes, and fungi composite soil samples were taken from the pots 1 day, 1 week, and 3 weeks after treatments. The samples were taken from the surface to 2 inches in

[1]Journal Series Paper No. 39, College Exp. Sta., University of Georgia, Athens, Georgia.

[2]Graduate Assistant and Associate Professor, respectively, Department of Agronomy, College Exp. Sta., University of Georgia, Athens, Georgia.

[3]Kindly furnished by Dow Chemical Co., Midland, Michigan, as a commercial preparation of sodium salt of 2,2–dichloropropionic acid Dowpon, containing 74% acid equivalent or 85% active ingredient.

depth. Plate counts of the soil microbial population were made using 5 plates of Thornton's medium (1) per treatment for each replication. Bacteria, actinomycetes, and fungi were counted at 1:100,000 dilution after 4 days incubation at room temperature (approximately 30° C.). Rose Bengal–streptomycin medium (1) was also used for counting fungi at the 1 week sampling period (at 1:4000 dilution).

In order to study the effect of dalapon on symbiotic nitrogen-fixing bacteria, the pots were arbitrarily divided into quarters, soybeans were planted in each pot 1 day, 1 week, and 3 weeks after applying dalapon treatments. Ten inoculated seeds per pot were planted at each date. The surviving plants were harvested August 10, (50 days from the beginning of the experiment) and their nodulation rated. The rating scale was as follows: good = 10, fair = 7, poor = 4, none = 1.

For determining the effect of dalapon on the nitrifying bacteria, the nitrate nitrogen levels of the soil were determined before dalapon treatment, 1 week after treatment and 3 weeks after treatment. As ammonium sulfate was applied uniformly to the soil, any differences in nitrate nitrogen content should be due mainly to differences in numbers and activity of the nitrifying bacteria. The nitrate nitrogen was determined by the phenoldisulfonic acid method of Prince (5).

RESULTS AND DISCUSSION

From the data shown in Table 1 it is evident that treating the soil with dalapon had no adverse effect on the total soil population, (combining bacteria, actinomycetes, and fungi). None of the treatments significantly differed from the check for each respective date of plating. The high microbial count which occurred in the first plating 1 day after treatment is assumed to be due to a high count initially in the field soil. The trend toward higher mean number of microorganisms for the 68-pound dalapon treatment at the 1-week date of plating seems to indicate a microbial build-up, but it was not statistically significant. Results for the 3-week date of plating again are similar to the first plating in their relationship to each other. Differences in microbial numbers between dates of sampling correspond to weather conditions during the experiment. Microorganisms were reduced in the soil by a series of hot days when air temperatures in the greenhouse reached 102° F. and above, just before the second plating was made. A series of cooler, cloudy days preceded the third plating.

Bacteria counts (Table 1) follow about the same pattern as for the total microorganisms. However, in the first plating, after 1 day, and in the third plating, 3 weeks after treatment, the numbers of bacteria for the 17 and 34 pound dalapon rates respectively, were significantly higher than the control. The number of actinomycetes (Table 1) for the 68-pound treatment was significantly higher than the control at the 1 week sampling period, possibly due to stimulation by the dalapon.

Table 1. Effect of dalapon applications on total microbial population, on soil bacteria and on soil actinomycetes.

Organism	Dalapon lbs/A.	Count x 100,000		
		After 1 day	After 1 week	After 3 weeks
Total population	Control	260	81	166
	17	281	78	192
	34	284	79	195
	68	258	110	170
Soil bacteria	Control	219	64	142
	17	239*	56	166**
	34	232*	57	174**
	68	212	82	142
Soil actinomycetes	Control	40	15	23
	17	37	20	24
	34	49	20	18
	68	42	24**	25

*Significantly higher than the control at the .05 level of probability.
**Significantly higher than the control at the .01 level of probability.

The soil fungi (Table 2) were significantly higher than the control 1 day following treatment for the 17 and 68 pound dalapon levels. No explanation is offered for this phenomenon. There was a trend for an increase in fungi for the 68 pound dalapon level 1 week after treatment as shown by counts on both Thornton's and Rose Bengal media.

Table 2. Effect of dalapon applications on soil fungi.

Dalapon lb/A	Thornton's medium			Rose Bengal-Streptomycin
	Count x 100,000			Count x 4,000
	June 22 after 1 day	June 29 after 1 week	July 3 after 3 weeks	June 29 after 1 week
Control	3.3	2.6	2.9	19.2
17	4.3*	2.4	2.0	17.4
34	3.6	2.1	2.8	19.9
68	4.8**	3.6	2.9	23.4

*Significantly higher than control at .05 level of probability.
**Significantly higher than control at .01 level of probability.

Soybeans planted 1 day, 1 week, and 3 weeks after dalapon application were uniformly nodulated. The data in Table 3 therefore, show the average nodulation ratings with dalapon treatments for all dates of planting. There were essentially no differences in nodulation in relation to dalapon treatment. The seemingly better nodulation of soybeans growing in dalapon treated soil is misleading. The reduced nodulation of the control plants is explained from the fact that the healthy plants from early plantings in the same pot competed seriously with the younger plants, thereby reducing nodulation. Soybeans which were planted immediately after dalapon treatment were severely injured with some killing, but from Figure 1 it can be seen that after 3 weeks the toxic effect of the herbicide had disappeared.

Table 3. Effect of dalapon applications on nodulation of soybeans.

Dalapon lb/A	Nodulation rating[1]
Control	6.7
17	8.0
34	8.5
68	9.3

[1]Rating scale: Good = 10, fair = 7, poor = 4, none = 1.

Figure 1. Soybean plants grown in pots receiving 0, 20, 40, and 80 pounds dalapon (0, 17, 34, and 68 pounds active ingredient) per acre. Young soybeans planted 3 weeks after dalapon treatment (shown on front side of each pot except in pot on right where they are on right side) show no toxicity symptoms. Those planted 1 day and 1 week after dalapon treatment show toxicity at all rates.

Any deleterious effect of dalapon on the symbiotic relationship of rhizobia on soybeans would probably be caused by the action of the herbicide through the medium of the plant and not directly on the bacteria. This was the relationship concluded by Carlyle and Thorpe (2) when working with the effects of 2,4–D on legumes and rhizobium bacteria.

Nitrification as reflected by the soil nitrate content was not influenced significantly by dalapon (Table 4). There was a trend, however, for reduced nitrate contents at the 1 week period for the 68 pound dalapon rate. After 3 weeks this effect had disappeared. The overall nitrate content of soils at the third sampling was reduced,

probably by plant uptake. The plants in the control treatments being larger took up the greatest amount of nitrates.

Table 4. Nitrate content of dalapon treated soil.

Dalapon lb/A	Ppm after 1 week	Ppm After 3 weeks
Control	201	59
17	189	76
34	176	83
68	130	73

As dalapon toxicity to soybeans had disappeared in 3 weeks, a build-up in microorganisms using it as energy should have occurred prior to that time. Actinomycetes were the only group significantly increased by dalapon at the 1 week sampling period. They may have played a role in decomposing the compound.

SUMMARY AND CONCLUSIONS

Dalapon at rates of 0, 17, 34, and 68 pounds per acre were added to Cecil sandy loam soil in the greenhouse. Soybeans were planted 1 day, 1 week, and 3 weeks after the dalapon treatments.

There was no effect of dalapon on the overall soil microbiological population except possibly to stimulate growth in some cases. Nitrates showed a trend toward being reduced in soil after 1 week for the highest rate of application. The fact that nitrates were as high in the pots treated with high rates of dalapon 3 weeks after treatment would indicate that the effect, if any, on nitrifying bacteria was temporary. There was no effect of dalapon on nodulation.

It is concluded that there is no harmful effect of recommended applications of dalapon on soil microorganisms, especially under climatic conditions that allow the microflora to break down the compound rapidly.

LITERATURE CITED

1. ALLEN, O. N. Experiments in Soil Bacteriology. Burgess Publishing Company. Minneapolis, Minnesota. 1951.
2. CARLYLE, R. E., and THORPE, J. D. Some effects of ammonium and sodium 2,4–D salts on legumes and Rhizobium bacteria. Amer. Soc. Agron. Jour. 39:929–936. 1947.
3. HOLSTUN, J. T., JR., and LOOMIS, W. E. Leaching and decomposition of 2,2–dichloropropionic acid in several Iowa soils. Weeds 4:205–217. 1956.
4. MAGEE, LYMAN A., and COLMER, ARTHUR R. The effect of herbicides on microorganisms. III. The effect of some herbicides on the respiration of Azotobacter. Appl. Microbiol. 3:288–292. 1955.
5. PRINCE, ARTHUR L. Determination of total nitrogen, ammonia, nitrates, and nitrates in soils. Soil Science 59:47–52. 1945.
6. SMITH, N. A., DAWSON, VIRGINIA T., and WENZEL, MARIE E. The effect of certain herbicides on soil microorganisms. Proc. Soil Sci. Soc. Amer. 10:197–201. 1945.
7. THIEGS, B. J. The stability of dalapon in soils. Down to Earth 11(2):2–4. 1955.

The Leaching of Monuron from Lakeland Sand Soil. Part I. The Effect of Amount, Intensity, and Frequency of Simulated Rainfall[1]

R. P. Upchurch and W. C. Pierce[2]

The rate of disappearance of a herbicide from soil is one of the key properties in determining its utility. In some cases it is desirable that a selected herbicidal concentration be maintained in the soil as long as possible. In other cases, rapid dissipation is desirable after a given effect has been produced. Leaching is a primary factor in the removal of many herbicides from soil (3, 5, 6).

Many studies have been conducted on the rate of leaching of herbicides from soil (2, 3, 4, 5, 6, 7). These studies have been concerned primarily with the effectiveness of a given amount of water in moving herbicide into and through a particular soil. Little attention has been given to the experimental conditions which might affect the results. Such factors as intensity and frequency of rainfall, soil temperature, soil density, rate of herbicide and soil moisture content have received inadequate emphasis.

The studies reported herein were undertaken to investigate the relative importance of rainfall in removing monuron [3–(*p*–chlorophenyl)–1,1–dimethylurea] from Lakeland sand soil. Special consideration was given to the attendant factors of rainfall frequency and intensity. Experiments reported in the literature show that the substituted urea herbicides are resistant to leaching. These experiments have been conducted with soils having higher clay and/or organic matter content than Lakeland soil (4, 6).

Materials and Methods

Lakeland sand soil to be used in leaching experiments was collected from a typical soil site in Northwest Florida. Samples were taken from each of six layers having the following depths: 0 to 2, 2 to 4, 4 to 8, 8 to 12, 12 to 24, and 24 to 36 inches.

The soil from each depth was air-dried, screened, and stored in closed containers until used. Soil columns 3 inches in diameter and 36 inches high were reconstituted in the laboratory from air-dry soil. For this purpose, six sections of monel metal pipe were used for each column. The wall thickness of the pipe was 3/16 inch. The ends of each pipe section were machine tooled to produce a flat surface so that the sections would be stable when stacked one on the other. Stop-cock lubricant was used between the metal sections to make a watertight seal. The two lower soil layers were packed

[1]Research conducted by the United States Air Force Armament Center, Elgin Air Force Base, Florida. Approved for publication by Major General Edward P. Mechling, Commander. Appreciation is expressed to Dr. D. D. Mason, Department of Statistics, North Carolina State College for his assistance in the statistical treatment of the data.

[2]First Lieutenants, United States Air Force.

in 12-inch sections, the two intermediate layers in 4-inch sections and the two upper layers in 2-inch sections.

An aqueous stock suspension of monuron containing 40.885 g/L was prepared prior to initiation of experimentation. This suspension was used throughout all experiments to prepare aliquots for each column and was stored at 2° C when not in use. For each experiment the stock suspension was warmed to room temperature and appropriately diluted so that the desired amount of monuron could be applied to each column in a 5.0-milliliter volume. Normally, 20.44-milligrams of monuron (40 lb/A) was applied to the top of each column by uniformly dispensing it over the soil from a 5-milliliter pipette.

Twenty-four hours after the addition of herbicide to the soil surface, simulated rainfall additions were started. Generally, a total of 4 inches of simulated rainfall was applied to each column of air-dry soil. This amount of water had been determined in preliminary experiments as the amount required to just wet the entire soil volume in the 36-inch column. The desired quantity of water was dispersed over the soil surface using a 1-pint polyethylene bottle having 22 uniformly spaced perforations in the bottom. The diameter of each perforation was estimated to be 1/16 inch. The bottles were supported above the columns by an extra 2-inch section of pipe mounted on top of each column. A 1/2-inch application of simulated rainfall (58-milliliters) drained from these bottles in approximately 3 minutes at atmospheric pressure.

The six sections of each column were disassembled 24 hours after the final water application had been made. A thin brass plate was used to separate the sections, and each section of soil was spread on an aluminum plate and allowed to air dry for a 48-hour period.

A representative 50.00 gram soil sample from each section was refluxed for 1.5 hours in a 1-liter round-bottom flask containing 60 grams of reagent grade sodium hydroxide dissolved in 240 milliliters of distilled water. This treatment resulted in the hydrolysis of monuron to *p*–chloroaniline, carbon dioxide, and dimethylamine. The resulting *p*–chloroaniline was collected by boiling the refluxed mixture at an elevated temperature until 70-milliliters of distillate had been collected in 8.3-milliliters of reagent grade concentrated hydrochloric acid. After dilution to a 100-milliliter volume, the samples were analyzed according to the method of Bleidner et al. (1) and determined spectrophotometrically on a Beckman DU spectrophotometer. Untreated soil samples from each depth were analyzed periodically and the averages of these analyses were used as soil banks.

All experiments were conducted in an air-conditioned laboratory in which the temperature varied from 65 to 75° F. Tap water was used as a source of simulated rainfall. Each experiment was repeated two or three times.

The Lakeland sand soil used in these studies commonly has a field capacity of 6 percent, a wilting percentage of 2 percent, and an exchange capacity of 1 to 2 milliequivalents per 100 grams in the

0 to 2-inch layer (8). The organic matter content was determined by dry combustion (700° C) to be 1.44, 1.15, 1.07, 0.84, 0.70, and 0.68 percent for the 0 to 2-, 2 to 4-, 4 to 8-, 8 to 12-, 12 to 24-, and 24 to 36-inch layers, respectively. The pH for these six layers was 5.4, 5.3, 5.4, 5.3, 5.2, and 5.3, respectively, as determined by glass electrode using a 1:1 soil:water ratio. Lakeland sand soil has a sand sub-soil with excessive internal drainage, having been formed from sands 20 to 80 feet deep.

RESULTS AND DISCUSSION

The effect of amount of simulated rainfall on leaching.

The influence of amount of rainfall upon the distribution of monuron in soil was studied in two separate experiments. The average results are presented in Table 1. Simulated rainfall was applied

Table 1. The amount of monuron recovered from various soil depths as influenced by the total amount of simulated rainfall application.

Inches of water applied[1]	Milligrams of monuron recovered[2]								Final depth wet soil inches
	Depth of soil layer—inches						Below 36 inches (in leachate)	Total	
	0–2	2–4	4–8	8–12	12–24	24–36			
1	15.87	2.37	0.29	0.00	0.00	0.00	——	18.53	8.0
2	11.90	3.96	2.76	1.18	0.30	0.00	——	20.10	18.0
4	5.91	3.67	3.82	2.22	3.80	1.64	——	21.06	36.0
8	2.77	2.01	2.29	1.54	3.67	4.97	4.58	21.83	36.0
12	1.76	1.35	1.21	1.34	2.34	3.19	10.40	21.59	36.0

L.S.D.—for testing differences between means at the same depth.
.05 level of significance—0.96
.01 level of significance—1.47
C.V. —11 per cent

[1]Water applied in ½-inch increments at 30-minute intervals.
[2]Monuron applied = 20.44 milligrams per column.

in increments of ½ inch at ½-hour intervals until the total amount of water desired had been applied to each column. Amounts totaling 1, 2, 4, 8, and 12 inches of water were applied to separate columns. For the 8- and 12-inch treatments, leachates were collected and analyzed for monuron content.

In these experiments, monuron was found to be readily leached from Lakeland sand soil when applied in soil sterilant quantities. Four inches of simulated rainfall, applied in eight increments at ½-hour intervals, leached 72 percent of a 40 lb/A application below 2 inches and 8 percent below 24 inches. The rate of removal in a geographical area having 4 to 5 inches of rainfall per month obviously would be appreciable. This rate of removal does not prevent monuron from being an effective material for controlling certain oak species which are difficult to kill. On Lakeland soil, 10 to 12 lb/A of monuron is sufficiently persistent to eradicate *Quercus laevis* during a 10 to 12-month period following application (8). The amount of monuron removed from the 0 to 2-inch layer was directly proportional to the amount of water applied until approximately 75 percent of the herbicide had been removed. Beginning with the

first inch of rainfall, each inch removed approximately 5.7 lb/A of monuron until 30 lb/A of monuron had been removed from the 0 to 2-inch layer. Each subsequent 1-inch of rainfall removed a progressively smaller amount of monuron.

The degree of monuron leaching reported here differs considerably from results of other studies where less sandy soils and/or soils higher in organic matter were used (4, 6). The results cited here might be expected to apply to the approximately 9,000,000 acres of sandhill soils present in the Southeastern United States and to a certain degree to the other more or less closely related soils of the Coastal Plains soil province of the same region.

The effect of frequency of simulated rainfall on leaching.

The influence of rainfall frequency was studied in three separate, identical experiments. The average results are presented in Table 2. In each of the experiments, eight ½-inch increments of simulated rainfall were applied to each column at varying time intervals. The intervals were: ⅛, ¼, 1, 2, 4, 8, 24, 48, and 72 hours. Thus, a total of 4 inches of simulated rainfall was applied to each of the time interval treatments. The period during which the eight increments were applied varied from less than 2 hours for the ⅛-hour treatment, to 21 days for the 72-hour treatment.

Table 2. The amount of monuron recovered from various soil depths as influenced by the frequency of simulated rainfall application.

Hours between applications[1]	Milligrams of monuron recovered[2]							Final depth wet soil—inches
	Depth of soil layer—inches						Total	
	0–2	2–4	4–8	8–12	12–24	24–36		
⅛	6.68	3.23	3.39	2.41	4.06	1.70	21.47	34.8
¼	6.32	3.75	3.71	2.31	3.89	1.04	21.02	34.0
1	7.10	3.83	3.66	2.07	3.88	0.92	21.46	34.3
2	7.77	4.80	3.88	1.77	2.54	0.51	21.27	33.0
4	8.84	5.03	3.51	1.48	1.22	0.04	20.12	29.8
8	9.33	4.50	3.61	1.61	1.31	0.11	20.47	28.6
24	11.79	3.23	2.21	0.93	0.65	0.03	18.84	25.6
48	12.12	2.75	2.33	0.69	0.49	0.00	18.38	23.7
72	12.42	2.63	1.89	0.61	0.42	0.00	17.97	21.5

L.S.D.—for testing differences between means at the same depth.
.05 level of significance—1.92
.01 level of significance—2.56
C.V. —30 per cent

[1]Total of 4 inches of water applied to each column at an intensity of ½ inch per application.
[2]Monuron applied = 20.44 milligrams per column.

The frequency of simulated rainfall had considerable effect upon the amount of monuron retained in the 0 to 2-inch layer of Lakeland soil. Increasing the interval of application from ⅛ to 24 hours increased the amount of monuron retained in the 0 to 2-inch layer from 31 to 63 percent of that applied. Further increases in interval of application brought about additional, but smaller, increases in retention by the 0 to 2-inch layer. In general, the amounts of monuron found in the lower layers of soil, as a function of rainfall frequency, were inversely related to the amount found in the 0 to

2-inch layers. The 2 to 4-inch layers did not follow this generalization. For these layers, increasing the interval of application from 1/8 to 4 hours resulted in an increase in the monuron content, just as for the 0 to 2-inch layers; whereas, further increases in the application interval caused a gradual decrease in the monuron content similar to that for the 4 to 8-inch and lower layers.

There is one obvious reason why the less frequent applications of simulated rainfall resulted in decreased leaching. The less frequent applications required the soil columns to be exposed to the atmosphere longer than in the case of the more frequent applications and, thereby, allowed a greater amount of evaporation to take place from the soil surface. The 1/4-hour treatments were exposed to the atmosphere only one day before disassembly; whereas, the 72-hour treatments were exposed 22 days. The difference in loss of water by evaporation is indicated by the amount of dry soil found in the bottom of each column (Table 2). The water lost by evaporation from the soil surface decreased the amount percolating through the soil column, resulting in a reduction of monuron leaching.

The recovery of monuron from columns receiving the less frequent applications of simulated rainfall was found to be low. The regression of amount of recovery per column on time required for treatment was calculated. The recovery was found to decrease by .1964 milligrams of monuron for each 24 hours of exposure. The standard error of this b value was .0501. Sixteen percent less monuron was recovered from the 72-hour treatment than from the 1/8-hour treatment (Table 2). This may be explained by the fact that the 72-hour treatment required monuron to be in intimate contact with moist soil for 22 days. During this period microbial decomposition of monuron may have occurred (4). Loss of monuron from the soil surface of the columns seems unlikely since exposure of air-dry soil samples to laboratory atmosphere for 20 to 30 days did not result in a loss of monuron.

In order to evaluate more completely the role of evaporation in the frequency effect, a supplementary experiment was conducted. The 1/4 and 24-hour treatments were replicated twice using plastic covers over the columns to minimize evaporation. These covers were removed only to allow for the addition of the eight simulated rainfall additions to each column. A small hole, $^1/_{16}$ inch in diameter, was made in the top of each plastic cover to maintain atmospheric pressure in the column. The difference between the rates of leaching for the 1/4- and 24-hour treatments (covered) indicated the role of the frequency effect over and above the associated evaporation factor. Along with the four covered columns, two uncovered columns were utilized to evaluate the evaporation factor in a different way. These two uncovered columns received the 24-hour treatment. Additions of water were continued at 24-hour intervals until the soil in these columns had been wet to a depth estimated to be as great as that obtained by applying exactly 4 inches of rainfall and using covers to prevent evaporation. Three extra 1/2-inch increments were necessary. The results of this supple-

Table 3. The amount of monuron recovered from various soil depths as influenced by the frequency of simulated rainfall application using evaporation compensation.

Hours between applications[1]	Milligrams of monuron recovered[2]							Final depth wet soil—inches
	Depth of soil layer—inches						Total	
	0–2	2–4	4–8	8–12	12–24	24–36		
¼ (column covered)	6.35	2.44	3.63	2.55	6.04	3.11	24.12	33.4
24 (column covered)	9.78	4.24	3.28	2.69	1.67	0.18	21.84	29.6
24 (column uncovered, 1½ in extra H_2O added)	7.05	3.60	2.98	3.29	1.81	0.23	18.96	36.0

L.S.D.—For testing differences between means at the same depth.
.05 level of significance—1.62
.01 level of significance—2.61
C.V. —19 per cent

[1]Total of 4 inches applied to the covered columns and 5½ inches to the uncovered column. Applications made at an intensity of ½ inch per application.
[2]Monuron applied = 20.44 milligrams per column.

mental study are shown in Table 3. The results from the covered columns show clearly that the frequency effect is explained only partially by the evaporation factor. When evaporation was essentially eliminated by covering the soil columns, the ¼-hour treatment caused 19 percent more monuron to be leached from the 0 to 2-inch layer than the 24-hour frequency. The comparable difference for uncovered columns was 32 percent. Where the water lost through evaporation was replaced by the addition of extra increments, no special effect of evaporation on leaching was observed other than that of simply decreasing the amount of water percolating through the column. Although some minor differences were observed, evaporation apparently has no sizable, direct effect on the leachability of monuron, nor does evaporation cause a special accumulation in a sub-surface layer as might have been anticipated. Some of the minor differences observed may be attributed to the fact that slightly more water was accidentally used to replace that lost through evaporation than was necessary.

In addition to the evaporation factor, two postulations can be made as to why more frequent water applications cause greater leaching of monuron from soil than less frequent applications. First, the effectiveness of a given water application in bringing about leaching possibly depends upon the total amount of monuron which is present in the soil solution. The amount in solution is probably greatest just after the application of an increment of water. It decreases thereafter as the water movement ceases and the monuron in solution throughout the soil profile reaches a new equilibrium between the adsorbed and solution phases. This new equilibrium would likely result in less total monuron in solution, since the monuron content would be more uniformly distributed throughout the soil and thus encounter more adsorbing surface.

Second, the rate of movement of water through the soil may also affect the amount of leaching. It seems likely that water from the more frequent applications moves through the soil more rapidly

than that from less frequent applications. This more rapid movement would allow less time for re-adsorption of monuron from percolating solution by the sub-surface layers with the result that accumulation of monuron would occur in the lowest possible layers. This possibility is indicated by the amount of retention by the 2 to 4-inch horizon with the ¼- and 24-hour (covered) treatments. Only 14 percent of the monuron entering the 2 to 4-inch horizon was adsorbed by this layer using the ¼-hour treatment; whereas, the corresponding value for the 24-hour treatment was 35 percent. In order to be directly comparable, these two values should be corrected for the fact that more total monuron entered the 2 to 4-inch layer when the ¼-hour treatment was used than when the 24-hour treatment was used.

The effect of intensity of simulated rainfall on leaching.

The influence of rainfall intensity was studied in three separate, identical experiments. The average results are presented in Table 4. In each of the experiments a total of 4 inches of simulated rainfall was applied to each of six columns. Increments of 1/16, ⅛, ¼, 1, 2, and 4 inches were used per application, constituting six intensities of simulated rainfall. Successive increments were applied at ½-hour intervals for each intensity until a total of 4 inches of simulated rainfall had been applied to each column. Approximately, 1, 1.5, 2, 5, 6, and 12 minutes were required for the application of each 1/16-, ⅛-, ¼-, 1-, 2-, and 4-inch increment, respectively.

Table 4. The amount of monuron recovered from various soil depths as influenced by the intensity of simulated rainfall application.

Inches of water applied per application[1]	Milligrams of monuron recovered[2]							Final depth wet soil inches
	Depth of soil layer—inches						Total	
	0–2	2–4	4–8	8–12	12–24	24–36		
1/16	5.82	4.42	4.77	2.18	2.31	0.74	20.24	31.3
⅛	5.75	4.11	4.46	2.29	3.30	1.29	21.20	33.3
¼	6.00	3.63	3.31	1.93	3.68	1.48	20.03	34.6
1	6.48	2.93	3.10	2.04	3.71	1.30	19.56	34.8
2	6.05	2.64	3.25	2.09	3.89	1.40	19.32	34.5
4	6.36	2.36	2.86	2.11	4.22	1.75	19.69	34.6

L.S.D.—For testing differences between means at the same depth.
.05 level of significance—1.75
.01 level of significance—2.34
C.V. —28 per cent

[1]Total of 4 inches of water applied to each column with applications at 30 minute intervals.
[2]Monuron applied = 20.44 milligrams per column.

The intensity of simulated rainfall had little influence upon the movement of monuron from the 0 to 2-inch layer of soil. Even though monuron is generally considered to be a relatively insoluble chemical in water (240 ppm at 25° C), its rate of solution seemed to be relatively unimportant in affecting its leaching from the soil surface under conditions used in this experiment. The intensity of simulated rainfall had an effect upon the amount of monuron leached into the lower horizons. The lowest intensities caused a

concentration of monuron in the 2 to 8-inch zone, with a correspondingly smaller amount being found in the 12 to 36-inch zone. Progressive increases in the intensity of application brought about a gradual decrease in the amount of monuron found in the 2 to 8-inch zone and a gradual increase in the amount found in the 12 to 36-inch zone. Intensity of simulated rainfall had no effect upon the amount of monuron found in the 8 to 12-inch zone. These conclusions are further substantiated by the fact that the linear component of the 0 to 2-inch data was not significant; whereas, the linear components for the 2 to 4- and 4 to 8-inch data were highly significant.

Intensity of simulated rainfall clearly affects the amount of monuron found in sub-surface soil horizons. This effect must be due to an influence of the intensity factor upon the amount of adsorption of monuron by the sub-surface soil horizons from the percolating solution. This influence may be brought about by the percolating solution moving through the soil column more rapidly in the case of the more intense applications of rainfall than for the less intense applications. The slower movement would allow more time for adsorption of the herbicide from solution in the case of the less intense applications. This slower movement causes herbicide to be concentrated in the upper sub-surface horizons of the soil.

The combined effects of amount, frequency and intensity of simulated rainfall on leaching.

Experiments on the effect of intensity and frequency of simulated rainfall on the distribution of monuron in soil indicate that there are at least two distinct steps involved. The first step involves the entrance of herbicide into solution, whether it be from solid herbicide particles at the soil surface or from the herbicide adsorbed on the soil at some point in the soil profile. The second step involves the adsorption of herbicide from the percolating solution by the soil. Any given variable may affect one or both of these steps. Experiments on the intensity of rainfall indicate that the rate at which water moves into the soil has little effect upon the solution step of the distribution process for monuron. Apparently, the entrance of monuron into solution from the solid phase is very rapid. Whether the monuron which is adsorbed on the soil surface transfers to the soil solution rapidly or slowly is not known. The adsorption step is very much affected by the rate of passage of the percolating solution. Another possible step in the distribution process is the movement of herbicide in the percolating solution as a suspension. In discussing the results of these studies, it has been assumed that monuron does not enter the percolating solution as a suspension.

These studies indicate that the factors of intensity and frequency of rainfall should receive consideration when leaching studies are being conducted. In the past, most investigators have selected a convenient intensity and frequency without much consideration of their inherent effects upon the distribution of herbicides. Further

studies are needed to determine the degree to which the findings reported here may apply to other soils and herbicides.

Among the three factors studied—amount, frequency, and intensity of rainfall—the amount factor would be most easily and directly correlated with the distribution of herbicide under field conditions. The factors of intensity and frequency might also be of practical importance even though under field conditions quite irregular intensities and frequencies are obtained. Rains occurring at less than 24-hour intervals would be expected to result in more leaching than equal amounts of rain occurring at greater intervals. Gentle showers would tend to concentrate the herbicide in the upper sub-surface horizons. The exact combined effect of the three factors is difficult to predict since any two rains constitute a specific amount-intensity-frequency relationship which normally changes with the advent of each successive rain. In this investigation these factors were studied individually and not in combination.

SUMMARY

The effects of amount, frequency, and intensity of simulated rainfall on the distribution of monuron in Lakeland sand soil were studied. Soil columns 3 inches in diameter and 36 inches high were reconstituted from air-dry soil using metal pipe sections to contain the soil. Monuron was applied to the surface of each column at a rate of 40 lb/A. Following the application of simulated rainfall to the columns they were disassembled and the soil from the six sections (0 to 2, 2 to 4, 4 to 8, 8 to 12, 12 to 24, and 24 to 36 inches) of each column was analyzed chemically for monuron content.

Monuron was found to be leached readily from Lakeland soil when present in soil sterilant quantities. Four inches of simulated rainfall applied in eight increments at ½-hour intervals leached 72 percent of a 40 lb/A application below 2 inches and 8 percent below 24 inches. Twelve inches of simulated rainfall applied in a similar manner leached 89 percent below 2 inches and 51 percent below 24 inches.

Intensities of rainfall varying from $^1/_{16}$ inch per application to 4 inches per application had little influence upon the amount of monuron removed from the 0 to 2-inch soil horizon. The less intense applications resulted in a greater accumulation of monuron in the 2 to 8-inch zone. More frequent applications of simulated rainfall resulted in a greater removal of monuron from the upper soil horizons than did less frequent applications. This was noticeable especially for rainfall applied more frequently than every 24 hours. Approximately one-half of the effect of frequency was due to the fact that less frequent applications allowed more moisture to evaporate from the soil surface, thereby making less moisture available to percolate through the soil.

Interpretation of the data was facilitated by assuming that the leaching process involves at least two steps; the entrance of herbicide into solution and the adsorption of herbicide on the soil from the percolating solution. The rainfall intensity factor apparently affects

the latter step but has little or no effect upon the former. The frequency factor affects both of the steps. The importance of amount, frequency, and intensity of rainfall in experimental work and under field conditions is discussed.

LITERATURE CITED

1. BLEIDNER, W. E., BAKER, H. M., LEVITSKY, M. and LOWEN, W. K. Determination of 3–(*p*–chlorophenyl)–1,1–dimethylurea in soils and plant tissue. Agr. and Food Chem. 2:476–479. 1954.
2. HANKS, ROBERT W. Removal of 2,4–dichlorophenoxy-acetic acid and its calcium salt from six different soils by leaching. Bot. Gaz. 108:186–191. 1946.
3. HERNANDEZ, T. P., and WARREN, G. F. Some factors affecting the rate of inactivation and leaching of 2,4–D in different soils. Amer. Soc. for Hort. Sci. 56:287–293. 1950.
4. HILL, G. D., MCGAHEN, J. W., BAKER, H. M., FINNERTY, D. W. and BINGEMAN, C. W. The fate of substituted urea herbicides in agricultural soils. Agron. Jour. 47:93–104. 1955.
5. HOLSTUN, J. T., JR., and LOOMIS, W. E. Leaching and decomposition of 2,2–dichloropropionic acid in several Iowa soils. Weeds 4:205–217. 1956.
6. OGLE, R. E., and WARREN, G. F. Fate and activity of herbicides in soils. Weeds 3:257–273. 1954.
7. ROSENFELS, R. S., and CRAFTS, A. S. Chlorate distribution and the effect of nitrate concentration on chlorate toxicity in soil columns. Hilgardia 14:70–79. 1941.
8. WOODS, FRANK W. Tests of CMU for forestry. Forest Science 1:240–243. 1955.

The Effects of Several Herbicides on Nitrification in a Field Soil Under Laboratory Conditions[1]

M. G. Hale, F. H. Hulcher[2] and W. E. Chappell

Introduction

The process of biological nitrification in soil is a two-step oxidation of the ammonium ion to nitrite and thence to nitrate and is largely caused by the autotrophic bacteria in the genera *Nitrosococcus, Nitrosomonas* and *Nitrobacter*. The biochemical activities of these soil microorganisms can be studied by using the percolation technique of Lees (7, 8). When studying the nitrifying organisms, an ammonium salt solution is bubbled under air pressure through a lift tube to the surface of a soil sample in a suitable container from whence it percolates downward through the soil and drains back into the reservoir from which it came. Air and moisture are thus constantly replenished in the soil and water logging is avoided. The value of the method lies in the fact that any substance introduced into the percolating fluid which affects the metabolism of the nitrifying organisms causes a change in the rate of conversion of the ammonium ions to nitrate ions. When the nitrate in the percolating fluid is in equilibrium with the nitrate in the soil, measurements of the nitrate nitrogen in aliquots of the percolating fluid are a measure of the rate of nitrification in the soil.

Quastel and Scholefield (13) have reported that if fresh soils are percolated with an ammonium salt solution, the population of organisms oxidizing the ammonium ion to the nitrate ion increases. The conversion to nitrate follows a sigmoid pattern as the population grows but a condition is ultimately reached in which the nitrification rate in a soil sample becomes constant. Lees and Quastel (9) have reported that this condition represents a saturation with bacterial cells of the available sites on the soil particles. In these saturated or "enriched" soils, the bacterial cells contained in thin films of moisture on the soil particles divide at a rate sufficient only to replace dead and disintegrating cells. Replenishment of the substrate periodically should result in a constant rate of nitrification limited primarily by the number of cells and their capacity to oxidize the ammonium ion. Such a stable system behaves like an enzyme system and its activity can be easily measured in the Warburg manometric apparatus. Quastel and Scholefield (13) have reported rates of oxidation as high as 92 percent of theoretically possible rates.

Repeated applications of chemicals to control weeds in crops may destroy beneficial microorganisms inhabiting the soil. Conversely such chemicals may have beneficial fungicidal and bactericidal properties (4). It has been shown that heterotrophic organisms are reduced in number and that respiratory rates are reduced (5, 6, 10).

[1]Contribution from the Department of Plant Pathology and Physiology, Virginia Agri. Exp. Sta., Blacksburg, Virginia.

[2]Present address: Department of Microbiology, Yale University, New Haven, Connecticut.

In the present investigation both the percolation method and the manometric method were used to study the effects of several herbicides on the rate of biological oxidation of the ammonium ion in soil.

METHODS AND MATERIALS

Groseclose silt loam was obtained from the top 3 inches of clover plots on the Virginia Agricultural Experiment Station farm at Blacksburg, Virginia. The soil was air dried, sieved and that portion which passed through a 4 mm mesh screen but was retained by a 2 mm mesh screen was used. Twenty or 30 gm of soil thus prepared was placed in a percolation apparatus similar to that described by Lees (7), and 0.5 gm of $CaCO_3$/20 gm soil was added to the soil surface to buffer the system at pH 8.5 to 8.8.

Ammonium chloride solution (0.01 M) was then added to the percolation reservoir and allowed to percolate through the soil under low pressure from an air line. The volume of the percolating fluid was maintained by periodically adding enough distilled water by weight to replace that lost by evaporation. All experiments were carried out at room temperature in the dark. For the percolation experiments, commercial formulations of 3–(*p*–chiorophenyl)1,1–dimethyl urea (monuron) and isopropyl N–(3–chlorophenyl)carbamate (CIPC) were added at the desired concentration of active ingredient directly to the percolating fluid. Periodically 1 ml aliquots of the percolating fluid were taken and analyzed for NO_3–N. Nitrate-nitrogen was determined colorimetrically using the phenol disulfonic acid–NH_4OH method of Russel et al. (14), and measuring the color density on a Beckman Model B spectrophotometer at 410 millimicron wave length.

The soil used for manometric measurements of ammonium ion oxidation was prepared by percolating the soil with ammonium chloride solution until a relatively high and constant rate of nitrification was attained through several changes of the percolating fluid. At the end of this period, usually several weeks, the average rate of nitrate formation was 24 micrograms per ml per 24 hours. Tubes of soil which were nitrifying at approximately this rate were selected and the contents of a single tube were used for each experiment. The soil was leached for several hours with distilled water until no nitrate or ammonium ions could be detected by spot tests of the leachate. It was removed from the tubes, spread on filter paper, allowed to dry for ½ hour and then chopped and mixed thoroughly with a spatula. One and one-half gram aliquots of soil so prepared were placed in conventional Warburg manometer flasks. One ml of 0.01 M NH_4Cl plus 1 ml of water or 1 ml of an aqueous solution of herbicide was added to the flasks. The final concentration of NH_4Cl was thus 0.005 M and the herbicide solutions were made up to twice the desired concentrations to allow for dilution when added to the flasks. Three-tenths ml of 30 percent KOH was placed in the center well with a 2 cm square of filter paper. After an equilibration period of 30 minutes oxygen uptake was measured at 15 minute intervals

for 2½ hours at 37° C. Treatments in each experiment were run in duplicate. The specific gravity of the soil was determined by means of a pycnometer and found to be 2.642. Since the 1.5 gm aliquots of soil used in the respirometer flasks weighed 1.2 gm when dried as for specific gravity measurements, the volume of the soil particles was calculated to be 0.45 cc and this value was used in the equation for calculating flask constants (16).

The herbicides used and their sources are listed in Table 1. These were added to the reaction flasks in such a manner that a known amount of the active chemical ingredient was present. Commercial formulations of herbicides were used for the following reasons: (1) they were readily available whereas the active ingredient of some was

Table 1. Source, chemical name and abbreviation or other designation of herbicides used.

Chemical name	Abb. or other designation	Source
Sodium 2,4-dichlorophenoxyethyl sulfate	2,4-DES (Sesone)	Carbide & Carbon
Isopropyl N-(3-chlorophenyl)-carbamate	CIPC	Columbia Southern Chemical Corp.
Alkanol amine salts of 4,6-dinitro-ortho-secondary butyl phenol	DNBP	Dow Chemical Co.
2,2-Dichloropropionic acid	Dalapon	Dow Chemical Co.
2-(2,4,5-Trichlorophenoxy)-propionic acid	2-(2,4,5-TP)	Dow Chemical Co.
3-(p-Chlorophenyl)1,1-dimethyl urea	Monuron (CMU)	E. I. DuPont de Nemours & Co.
Sodium pentachlorophenate	PCP	Monsanto Chemical Company

not readily obtainable in pure form; (2) commercial formulations are applied as herbicides in the field and their effects on the nitrifiers should be studied; (3) some of the pure chemicals are difficult to dissolve in water and hence must be emulsified or suspended by use of other agents. Such agents are incorporated into commercial formulations. In interpreting the results it should be borne in mind that some of the effects may be caused by materials other than the active ingredient and the effects of the chemical itself may be increased or decreased because of other materials in the formulation.

RESULTS

When fresh soil is percolated with an ammonium chloride solution, the nitrifying organisms proliferate at the expense of adsorbed ammonium ions (13). This population growth follows a sigmoid pattern as shown in Figure 1. One hundred ml of 0.01 M NH_4Cl solution contains enough ammonium ions to produce 140 micrograms per ml of nitrate nitrogen upon oxidation; therefore, 140 micrograms per ml represents the maximum amount in the solution. This value was approached in the NH_4Cl control which attained a maximum conversion of 92.8 percent of theoretical in about 24 days. When CIPC at 20 and 40 ppm of the ammonium chloride percolating solution was added, the rate of cell proliferation was reduced, as evidenced by a reduced rate of nitrate formation and a longer lag

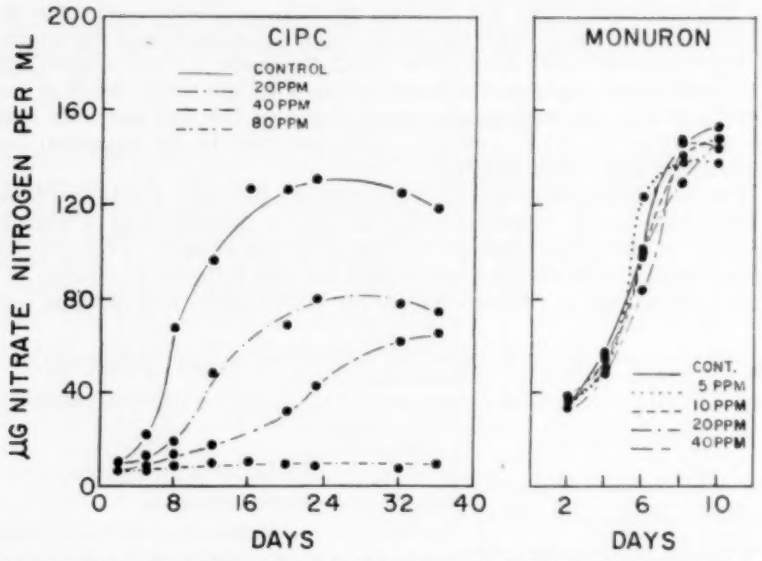


Figure 1. Rate of proliferation of nitrifying bacteria in fresh field soil percolated with 0.01 M NH_4Cl solution in the presence of CIPC (left) and monuron (right). Each point represents the average of two replicates.

phase of the growth curve. Eighty ppm CIPC completely inhibited growth since the rate of nitrate formation remained below that of soil treated with water alone (not shown). Addition of 5, 10, 20 and 40 ppm of monuron had no inhibiting effect on the growth of the nitrifiers as shown in Figure 1.

Enriched soils, when re-percolated with NH_4Cl, show no lag phase and nitrify at constant rates. Since growth is limited to cell replacement, treatments of enriched soil affect the nitrification process *per se*. Figure 2 shows the results of experiments in which CIPC and monuron were added to the percolating fluid of enriched soils. Forty and 80 ppm CIPC only slightly inhibited nitrification, but 160 ppm inhibited the process almost 90 percent on the third day and inhibition continued for the duration of the experiment. Forty ppm monuron inhibited nitrification by 50 percent on the third day, while concentrations less than 40 ppm caused no appreciable effect.

Herbicides are applied in the field to unenriched soils and may remain there for an extended period of time. To test the effect of a long period of exposure of the nitrifying bacteria to the herbicides, fresh field soil was percolated for 26 days with water and with 40, 80 and 160 ppm aqueous solutions of CIPC (pre-treatment). At the end of this period, the soil was washed by several changes of water in the percolating apparatus over a period of 2 days and then the soil was re-percolated using NH_4Cl solution. The results of this re-percolation are presented in Figure 3. The soil pre-treated with water oxidized the ammonium ion at a rate comparable to that

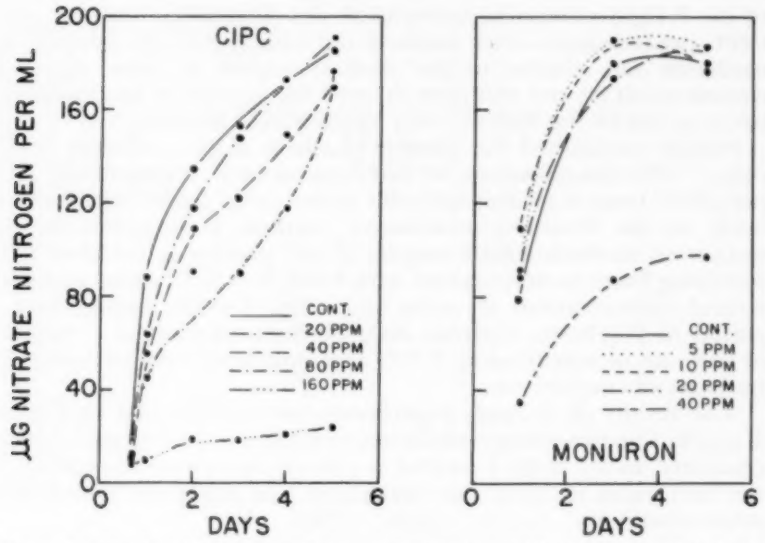


Figure 2. Rate of nitrification of soil organisms in enriched soil percolated with 0.01 M NH_4Cl solution in the presence of CIPC (left) and monuron (right). Each point represents the average of two replicates.

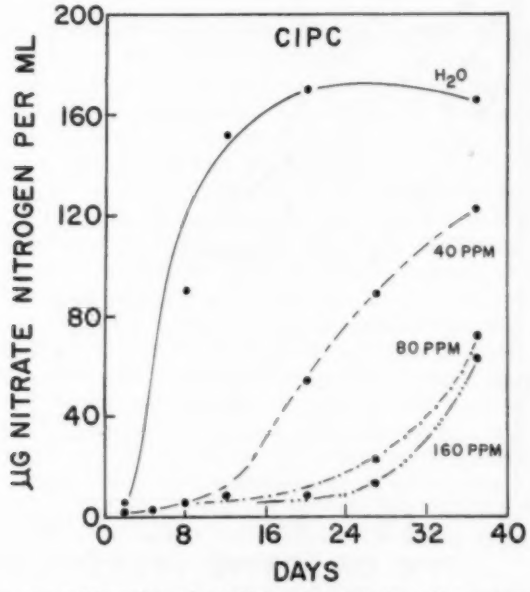


Figure 3. Rate of proliferation of nitrifying bacteria in soil previously percolated with aqueous solutions of CIPC for 26 days, washed several times with water, and then re-percolated with 0.01 M NH_4Cl. Previous treatments are indicated.

of the NH_4Cl control in unenriched soil (Figure 1). The 40 ppm CIPC pre-treatment, after washing and adding NH_4Cl, also had an oxidation rate similar to the same treatment of fresh soil. Pre-treatments of 80 and 160 ppm delayed the growth of the nitrifying bacteria, but by the 30th day they had begun to recover.

Having established the pattern of effects of two different herbicides, CIPC and monuron, on nitrification over comparatively long periods of time, it seemed desirable to test other herbicides. Use was made of the Warburg manometric method as described in the section on methods. Small samples of soil previously enriched with nitrifying bacteria were treated with 0.005 M NH_4Cl alone and with several concentrations of seven herbicides. Oxygen uptake over a period of 2½ hours replaced NO_3–N determination as a measure of the rate of nitrification. CIPC and monuron were included for purposes of comparison.

The results of 16 such experiments are summarized in Figures 4 and 5. The percentage inhibition or stimulation of oxygen uptake compared to an NH_4Cl control is plotted against concentration of the herbicides in ppm. No correction was made for endogenous respiration.

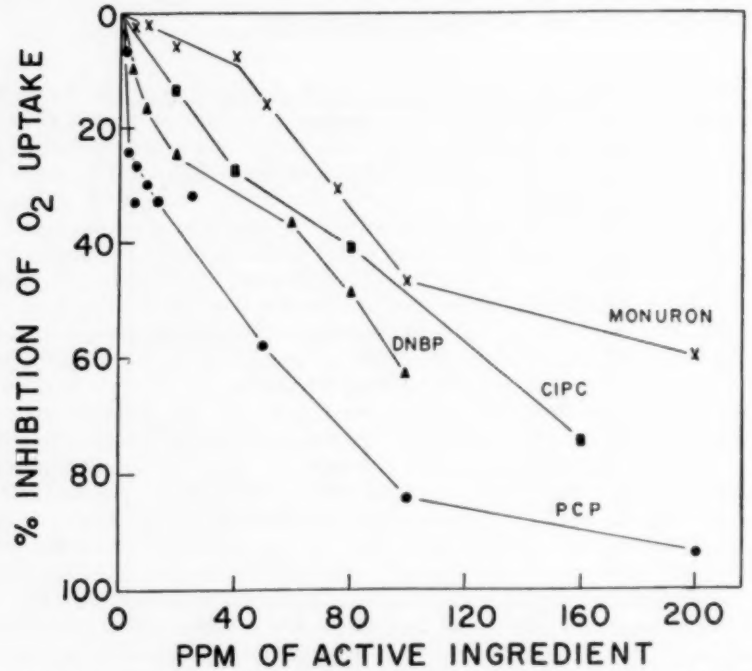


Figure 4. Percent inhibition of oxygen uptake of 1½ gm of soil after 2½ hours at 37° C in the presence of 0.005 M NH_4Cl and the herbicides and concentrations indicated.

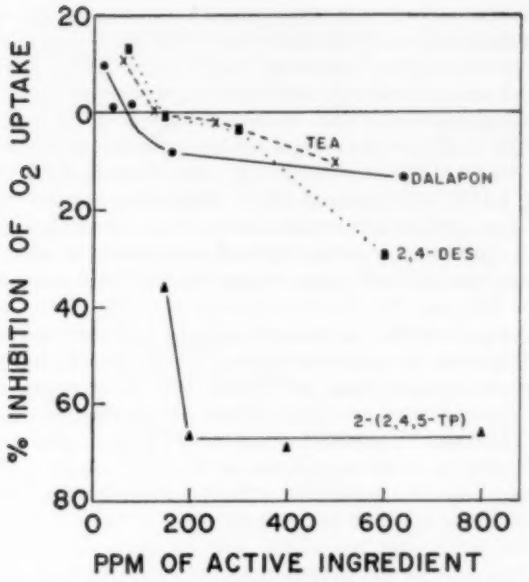


Figure 5. Percent inhibition or promotion of oxygen uptake of 1½ gm of soil after 2½ hours at 37° C in the presence of 0.005 M NH_4Cl and the herbicides and concentrations indicated.

In some preliminary experiments the O_2 uptake of enriched soils suspended in water exceeded expectations. This O_2 uptake would be that of the endogenous respiration of the nitrifiers plus the respiration of other organisms. There could have been enough substrate from natural sources in the soil to sustain a high rate of endogenous O_2 uptake, or the leaching process might not have removed all of the NH_4Cl substrate with which the soil had been percolated. Although no ammonium ion could be detected in the leachate some might have remained adsorbed on the soil colloids or on the surface and within the cells of the organisms.

Consequently an attempt was made to measure the respiration of the organisms in the absence of soil by preparing and percolating tubes of silica gel which were inoculated with a small amount of enriched soil. After the silica gel was enriched, aliquots were placed in manometer flasks and the O_2 uptake of the enriched silica gel was measured in the usual manner. The O_2 uptake of aliquots suspended in water was 41 µl while that suspended in 0.005 M NH_4Cl was 126 µl. These results are comparable to the results of the water and ammonium chloride controls for all the manometric experiments reported. These were pooled and the mean calculated to be 51 µl and 120 µl of O_2 utilized respectively.

Since there was no substrate for the heterotrophic organisms in the silica gel it would appear that the largest portion of the O_2 uptake in water is in reality a measure of the endogenous respiration of the

nitrifiers. How much of this was caused by the residual ammonium ions was not determined. The portion of the total respiration attributed to other organisms appeared to be negligible, hence, results are presented as percentage inhibition or stimulation compared to the NH_4Cl control without substracting the values obtained for the water control. Other investigators have shown that correction for endogenous respiration is not always valid (i.e. 3, 11).

Monuron, CIPC, DNBP and PCP inhibited oxygen uptake (Figure 4) and the inhibition increased as the concentration was increased. PCP showed the most marked inhibition at all comparable concentrations and at 200 ppm almost completely retarded oxygen uptake.

Dalapon and 2,4–DES increased oxygen uptake at the low concentrations between 50 and 150 ppm (Figure 5). At higher concentrations, oxygen uptake was inhibited, but only slightly. 2–(2,4,5–TP) exerted a more depressive effect upon oxygen uptake than dalapon or 2,4–DES. Triethanol amine (TEA) is not an herbicide but was included in these experiments to test the effect of an amine. It had a slight stimulatory effect at low concentrations and a slight inhibitory effect at high concentrations.

DISCUSSION

When the respiration rates of microorganisms in enriched soil were determined by measuring the oxygen uptake for 2½ hours, it was found that concentrations of CIPC between 80 and 160 ppm inhibited respiration from 40 to 80 percent. Such inhibition of respiration by CIPC is in agreement with the results of Quastel and Scholefield (13) who showed that compounds having the basic carbamic acid structure such as urethane would inhibit respiration of the nitrifiers.

In experiments not included commercial formulations of CIPC were more effective in inhibiting O_2 uptake at concentrations above 40 ppm than the unformulated technical grade chemical. At 40 ppm and below there was no difference between unformulated and formulated chemical. This could be explained on the basis of the low solubility of CIPC in water. No other unformulated chemicals were tried.

It is apparent that treatment with inhibitory concentrations of CIPC for 2½ hours did not kill all the organisms since some respiration did occur. Furthermore, treatment of soil for one month after which the soil was washed and re-percolated with NH_4Cl solution showed that at least some of the nitrifying organisms had survived these treatments. The long lag period before nitrification rates increased appreciably in these recovery experiments may be explained in one of two ways. Either the washing procedure did not remove all of the CIPC and it continued to inhibit, or else the organisms were so reduced in numbers that a long time passed before the population increased to a point where nitrification occurred at a noticeable rate. If the CIPC was not removed by the washing procedure, the eventual recovery could be explained on the basis of CIPC

disappearing from the soil. Biological destruction of CIPC in soil has been shown by Hulcher (unpublished) to be caused by fungi and bacteria, isolated from soil percolated with CIPC, which can use this chemical as a sole source of energy. Evaporation and biological destruction of IPC (isopropyl–N–phenylcarbamate) and CIPC in soil have been reported by other investigators (1, 2, 12, 15).

Manometric measurements of the inhibition of nitrification by CIPC are in agreement with those measured by the percolation method if the data from the third day of percolation are used for comparison. At concentrations of 80 and 160 ppm the inhibition of nitrate formation was 40 and approximately 90 percent respectively as compared with 40 and approximately 80 percent respectively for the manometric data. Such agreement was not shown for monuron. At 40 ppm in the percolation procedure, nitrate formation was inhibited 50 percent on the third day, but in the manometric procedure 40 ppm inhibited the process only 6 percent. Even at 200 ppm the oxidation was inhibited only 60 percent by monuron in a 2½ hour period.

The fact that monuron did not inhibit growth of the nitrifying organisms and inhibited nitrification in enriched soils only at the highest concentration used, may indicate that this compound is not as detrimental to the nitrifying organisms in soil as CIPC when used at the usual field application rates.

A comparison of herbicides, field application rates and concentrations which inhibited respiration by 50 percent are presented in Table 2. The amount of herbicide applied to 1 cm^2 of soil was calculated from recommended rates of field application. Since the specific gravity of the soil used was determined to be 2.642, 1 gm of soil would represent a volume of 0.38 cc. Therefore, micrograms per square centimeter would be equivalent to ppm at a depth of 0.38 mm if soil moisture, leaching, volatilization, and decomposition were ignored as factors affecting field concentrations. Since these factors do operate in the field and would cause further reductions in concentrations than those shown in Table 2, it becomes apparent that the effects on nitrifiers in the plow layer of soil may be negligible. Furthermore, Magee and Colmer (10) have found that inhibition of respiration does not necessarily mean destruction of the soil organisms as cells of *Azotobacter agile* remained viable when exposed

Table 2. Herbicides, usual field application rates and concentrations which inhibit O_2 uptake by 50%.

Herbicide	Usual field appl. rate of active ingredient		Ppm of active ingredient inhibiting O_2 uptake by 50%
	Lb/A	ug/cm^2 (ppm in 0.38 cc soil)	
Monuron	0.8	9	120
CIPC	4.0	45	100
PCP	17.6	197	40
DNBP	6.0	67	80
Dalapon	4.3	48	—
2,4–DES	2.7	30	—
2(2,4,5–TP)	1.5	17	175

to concentrations of 2,4–dichlorophenoxy-acetic acid in excess of those which completely inhibited respiration. Measurements of respiration rates for short periods of time may serve only as one indication of the effects of herbicides on soil microorganisms.

Further studies of the effects of these chemicals on biological nitrification in soil should be undertaken under field conditions before an accurate and sound evaluation of the significance of herbicide treatments upon soil fertility can be made.

SUMMARY

The effects of isopropyl N–(3–chlorophenyl)carbamate (CIPC) and 3–(*p*–chlorophenyl)1,1–dimethyl urea (monuron) on growth and nitrification rates of soil nitrifying organisms were studied by the soil percolation method. Results of these studies were compared with measurements of respiration rates obtained by the conventional Warburg manometric method for the same two herbicides and five others.

The rate of conversion of the ammonium ion to the nitrate ion when fresh field soil was percolated with an ammonium chloride solution containing varying concentrations of CIPC and monuron, was inhibited by CIPC in direct proportion to the concentration of the herbicide, but was not inhibited by monuron. Eighty ppm of CIPC completely inhibited growth of the nitrifying organisms but up to 40 ppm monuron was ineffective.

When soil, previously enriched in nitrifying organisms by percolating with ammonium chloride solution until a constant rate of nitrification was obtained, was subsequently percolated with an ammonium chloride solution containing varying concentrations of CIPC and monuron, nitrification was inhibited 90 percent by 160 ppm CIPC and 50 percent by 40 ppm monuron.

Comparison of oxygen uptake of soil previously enriched with nitrifying microorganisms and treated with several concentrations of seven herbicides in Warburg manometer flasks showed that sodium pentachlorophenate (PCP), 4,6–dinitro-ortho-secondary-butyl phenol (DNBP), CIPC and monuron were the most inhibitory. The inhibition of respiration was greatest with PCP. A comparison of the rates of nitrification as measured by formation of nitrate in the percolation method and oxygen uptake in the manometric method showed fair agreement for CIPC but not for monuron.

A comparison of the approximate concentrations of herbicides used in the field for chemical weed control and concentrations which caused a 50 percent inhibition of oxygen uptake by the nitrifying soil microorganisms was made. It was shown that the concentrations of herbicides which inhibited respiration by 50 percent would not occur at usual field application rates and that there would be little or no detrimental effect on soil nitrification.

ACKNOWLEDGEMENT

These studies were partially supported by a grant from the Columbia Southern Chemical Company.

LITERATURE CITED

1. ALDRICH, R. J. Residues in soil. Symposium on the formation and action of herbicides. Jour. Agric. and Food Chem. 1:257–260. 1953.
2. ANDERSON, W. P., LINDER, P. J., and MITCHELL, J. W. Evaporation of some plant growth regulators and its possible effect on their activity. Science 116:502–503. 1952.
3. BLUMENTHAL, H. J., KAFFLER, H., and GOLDSCHMIDT, E. P. The rate of endogenous respiration as affected by oxidation of exogenous substrates. Science 116:475–477. 1952.
4. CHAPPELL, W. E., and MILLER, L. I. The effects of certain herbicides on plant pathogens. Plant Disease Reporter 40:52–56. 1956.
5. GAMBLE, S. J., MAYHEW, C. J., and CHAPPELL, W. E. Respiration rates and plate counts for determining the effect of herbicides on the heterotrophic soil microorganisms. Soil Science 74:347–350. 1952.
6. KRATOCHVIL, D. E. Determination of the effect of several herbicides on soil microorganisms. Weeds 1:25–31. 1951.
7. LEES, H. A simple automatic percolator. Jour. Agric. 37:27. 1947.
8. ————. The soil percolation technique. Plant and Soil 1:221. 1949.
9. ————, and QUASTEL, J. H. The site of soil nitrification. Biochem. Jour. 40:815–823. 1946.
10. MAGEE, L. A., and COLMER, A. R. Some effects of 2,4–dichlorophenoxy acetic acid upon Azotobacter as measured by respiration inhibition. Weeds 4:124–130. 1956.
11. MOSES, V., and SYRETT, P. J. The endogenous respiration of microorganisms. Jour. Bact. 70:201–204. 1955.
12. NEWMAN, A. S., DEROSE, H. R., and DERIGO, H. T. Persistence of isopropyl–n–phenyl carbamate in soils. Soil Science 66:393. 1948.
13. QUASTEL, J. H., and SCHOLEFIELD, P. G. Biochemistry and nitrification in soil. Bact. Rev. 15:1–53. 1951.
14. RUSSELL, J. O., JONES, E. G., and BOBBITT, G. M. Temperature and moisture factors in nitrate production. Soil Science 19:381–398. 1925.
15. STEVENS, L. F., and CARLSON, R. F. Effects of Chloro IPC on various crops and its residual properties in various soils. PROC. NEWCC pp. 33–44. 1952.
16. UMBREIT, W. W., BURRIS, R. H., and STAUFFER, J. F. Manometric techniques and tissue metabolism. Burgess Pub. Co., Minn. 1951.

Interception of Herbicidal Sprays by Oats and Its Relation to Alfalfa Stands[1]

K. P. Dorschner and K. P. Buchholtz[2]

Forage legumes are often injured when herbicides, such as 2,4–dichlorophenoxyacetic acid (2,4–D), are applied to control weeds in fields of grain containing legume seedlings. At times the legume seedlings are not injured materially but in many instances the herbicide applications result in a moderate or even drastic thinning of the stand. Various factors have been suggested to account for the variability in results observed.

The date of herbicidal application is known to influence the responses obtained. Generally, better alfalfa stands have been obtained when the grain is 8 to 10 inches tall at time of spraying. However, Miller and Dunham (4) detected no differences in legume stands when early and late herbicidal treatments were compared. Willard and Bernard (7) reported that, in general, the injury to alfalfa seeded in oats decreased as the size of the oats increased at time of spraying. Churchill and Grigsby (1) found that the legume stand was maintained more satisfactorily in oat plots seeded to alfalfa when 2,4–D applications were made early in the season when the oats and the legume seedlings were small.

The abundant shade produced by a grain-leaf canopy may cause companion legume seedlings to become etiolated and structurally weak. Applications of herbicides to plants in this condition may be particularly harmful. Conversely, it is also true that a dense grain- or weed-leaf canopy protects the sensitive legumes somewhat from chemicals that are applied to control weed infestations.

Differential responses of plants to treatments with a constant amount of herbicide applied in aqueous sprays of different volumes have been studied by a number of workers. Smith (6) found that 2,4–D was applied most efficiently to kidney bean plants at a volume rate of 10 to 20 ml/sq. yard or 13 to 26 gal/A. Miller and Dunham (5) reported that applications of 2,4–D and 2–methyl–4–chlorophenoxyacetic acid (MCPA) to flax under-seeded with legumes were less toxic when spray volumes of 10 gal/A were used than with 40 gal/A.

The ability of a drop of 2,4–D solution to wet a waxy surface, such as a leaf, is known to vary with the concentration of the herbicide in the spray solution (2). Droplets from the more concentrated solutions spread to a greater extent. It is also likely that droplets of this

[1]Contribution from the Dept. of Agronomy, Wisconsin Agr. Exp. Sta., Madison, Wisconsin. Published with the approval of the Director of the Wisconsin Agr. Exp. Sta. Part of a thesis submitted by the senior author to the Graduate School of the University of Wisconsin in partial fulfillment of the requirements for the Ph.D. degree.

[2]Formerly Grad. Asst. in Agronomy, now Section Leader Herbicide Research, Niagara Chemical Division, Food Machinery and Chemical Corporation, Middleport, N. Y. and Prof. of Agronomy, University of Wisconsin, Madison, Wisconsin, respectively.

type develop more intimate contact with the leaf surface and allow absorption to occur more readily. On the other hand, sprays applied in higher volumes provide greater numbers of droplets and presumably a more thorough coverage of the leaf results. Another variable is the distribution of droplet sizes when low and high volume sprays are employed. Low volumes of spray are usually associated with greater percentages of small droplets than are the high spray volumes. It is also possible that the relatively small spray droplets from a 5 gal/A application would not penetrate a grain and weed leaf canopy as well as would the relatively large droplets derived from a spray applied in a volume of 40 gal/A.

MATERIALS AND METHODS

Randomized complete block experimental designs with four replications were used in all field trials with the exception of one trial in 1953. Field plots were established on a planting of Mindo oats seeded to Ranger alfalfa. The grain was sown with a drill having 6-inch row spacings. Alfalfa was seeded with a corrugated-roller seeder immediately after sowing the oats. Plots were 6 by 12 feet in size with 1-foot alleys between adjacent plots. The rates of seeding were 1.5 bushels of oats and 8 pounds of alfalfa per acre. Seeding was done during the first week in May in 1952 and 1953 with one exception in 1953.

One study, to determine the relationship of spray volume to spray interception and to observe the effects on alfalfa seedlings, was conducted in both 1952 and 1953. The triethanolamine salt of 2,4–D was applied at rates equal to 1.0, 0.5 and 0.25 lb/A in water equivalent to 5, 10, 20 and 40 gal/A. The sprays were applied with a bicycle sprayer using a pressure of 40 psi. Spraying Systems Co. nozzles 800067, 8001, 8002 and 8004 were used for the application of the 5, 10, 20 and 40 gal/A of spray, respectively. In all cases where reference is made to 2,4–D application rates, the stated amounts refer to the acid equivalents. Spray treatments were applied when the natural height of the oats was about 8 inches in 1952 and 12 inches in 1953.

An attempt was made to determine the amount of spray intercepted by the oat leaf canopy. The technique used was as follows: Glass microscope slides, 1 by 3 inches in size, were placed on holders so that 3 slides were located at the existing grain height and 3 at the height of the underseeded legume in each plot. To avoid double coverage each slide was located in the middle of the area covered by a single spray nozzle. After the spray applications were made, the slides were collected and allowed to dry. The slides were then removed to the laboratory where those representing each height level on each plot were grouped and the retained 2,4–D residue quantitatively removed by scrubbing in distilled water. Aliquots of the eluted materials were taken and the optical density determined in a Beckman Model DU spectrophotometer at 2835 angstroms as described by Dorschner and Buchholtz (3). The resulting optical

densities were converted to pounds of 2,4–D acid equivalents per acre.

By measurement of the 2,4–D deposition it was possible to determine the percent reduction in the spray application due to the protection of the grain leaf canopy. This procedure also provided a measurement of the actual amount of 2,4–D applied to the plots and allowed the calculation of the error inherent in the application techniques.

The oats were harvested at maturity and immediately afterwards the stubble was clipped and the stubble, straw and trash removed. Data on the stand and yields of oats were not obtained in this study. Alfalfa plant counts were obtained in September, approximately 6 weeks after removal of the oat crop, from 3 quadrats, 2 sq. ft. in size, located at random in each plot.

A second study was concerned with the influence of the height of the grain at time of spray application on the interception of the spray and on the survival of the alfalfa seeded in the grain. One such trial was conducted in 1952 and two trials in 1953. Plot preparation and the experimental design employed were similar to that described above. In 1953 one trial was seeded during the first week in May and the second during the fourth week to give a range of environmental conditions. Only three replications were used in the latter trial.

In the trials in both 1952 and 1953 a triethanolamine salt of 2,4–D was applied at rates equal to 1.0, 0.5 and 0.25 lb/A in water equivalent to 20 gal/A. One series of plots was sprayed when the oats were 6 inches tall, a second series when the oats were 12 inches tall and third when the oats had reached a height of 18 inches.

The spray applications were collected on glass slides located at the upper level of the grain leaves and at the level of the taller alfalfa seedlings. Quantities of 2,4–D collected on the slides was determined as previously described. All plots were clipped, raked and the trash removed following the harvest of the oats at maturity in late July. Alfalfa seedlings were counted in 3 quadrats, each 2 sq. ft. in size, in each plot approximately 6 weeks after harvest of the oats.

RESULTS AND DISCUSSION

Volume of spray studies.

The amount of spray solution penetrating the grain-leaf canopy to the level of the underseeded legumes was found to vary with the volume of the applied spray. The differences were greater in 1953 than in the 1952 trial, probably due to the taller growth present when the applications were made in the latter year. In 1952 the oats tillered well and produced a tall, dense stand. In 1953 the growth of the oats was shorter and fewer tillers were produced. Data presented in Table 1 show that as much as 50 percent of the spray was intercepted in the 1952 trials. In 1953 the interception was considerably less. There was a definite trend for greater percentages of the low-volume spray applications to be intercepted by the leaf

canopy. This was most noticeable in 1953 when 39 percent of the 2,4–D applied in 5 gallons of spray per acre was intercepted but only 8 percent when applied in 40 gallons. Differences between high and low volume sprays were less marked in 1952 when a dense and taller leaf canopy was present.

The data included in Table 1 also allows a comparison of the actual amount of the 2,4–D applied to the plots, based on collections made at the oat-leaf level, with the intended application rate. An experimental error of about 7.5 percent in 1952 and 12.0 percent in 1953 was apparent.

Table 1. 2,4–D applications collected at oat and alfalfa leaf levels after use of 4 volumes of spray.

Volume gal/A	Appl. lb/A	1952			1953			Ave. reduction in spray application
		2,4–D collected—lb/A		Appl. red. pct.	2,4–D collected—lb/A		Appl. red. pct.	
		Oat level	Alfalfa level		Oat level	Alfalfa level		
5	1.00	1.05	0.48	54.3	0.94	0.59	37.2	
	0.50	0.55	0.23	58.2	0.44	0.35	20.5	
	0.25	0.30	0.15	50.0	0.30	0.21	30.0	
Ave.				54.2			29.2	41.7
10	1.00	0.98	0.52	47.0	0.92	0.65	29.4	
	0.50	0.54	0.32	41.0	0.52	0.39	25.0	
	0.25	0.25	0.17	32.0	0.29	0.22	24.1	
Ave.				39.9			26.2	33.1
20	1.00	1.08	0.59	45.4	0.84	0.63	25.0	
	0.50	0.54	0.36	33.3	0.48	0.38	20.8	
	0.25	0.29	0.19	34.5	0.25	0.21	16.0	
Ave.				37.7			20.6	29.2
40	1.00	1.02	0.51	50.0	0.83	0.74	10.8	
	0.50	0.54	0.37	31.5	0.37	0.35	5.4	
	0.25	0.26	0.16	38.5	0.20	0.18	10.0	
Ave.				40.0			8.7	24.4

Stand counts, calculated as percent of the untreated check areas and shown in Table 2, indicate that the resulting stands of alfalfa seedlings averaged 48 percent of the untreated check plots after treatment with 2,4–D in 5 gallons of spray per acre. Stands of 51, 41 and 38 percent remained after treatment with 10, 20 and 40 gallons of spray per acre, respectively. Statistical analyses revealed that these stands, treated with different spray volumes, were not significantly different in either year. The data show a trend for the plots treated with the spray applications having the least interception, the 40 gal/A volume, to have the thinner stands. A more exact relationship with spray volume interception was probably obscured by the poorer leaf-wetting characteristics of the higher volume sprays.

Table 2. Alfalfa stands after treatment with 2,4–D at 3 rates in 4 volumes of spray.

Volume gal/A	Appl. lb/A	Alfalfa stands—pct. check			
		1952	1953	Volume ave.	Appl. ave.
5	1.00	31.5	22.2		19.8
	0.50	33.3	64.2		47.2
	0.25	73.5	64.8		66.3
Ave.		46.1	50.4	48.3	
10	1.00	25.3	22.8		
	0.50	67.9	49.4		
	0.25	77.7	61.1		
Ave.		56.9	44.4	50.7	
20	1.00	9.9	20.4		
	0.50	34.6	53.7		
	0.25	62.3	65.4		
Ave.		35.6	46.5	41.1	
40	1.00	11.1	15.4		
	0.50	30.9	43.2		
	0.25	57.4	67.9		
Ave.		33.1	42.2	37.7	
Check stand-plants/2 sq. ft.		16.2	13.1		

The increased toxicity of 2,4–D with the higher rates of application is clearly evident. Applications of 0.25 lb/A reduced stands of the alfalfa about 33 percent while the 1.0 lb/A rate reduced the stands approximately 80 percent.

Height of grain on spray interception and toxicity.

The second study was conducted to test the significance of the protection provided alfalfa seedlings, by grain of varying heights, when herbicidal chemicals are applied. By using glass-slide collections, it was found that the protection of the small legume seedlings from herbicidal sprays varied with the height of the grain at the time of application. The data in Table 3 show that sprays applied when the grain was 6, 12 and 18 inches tall were intercepted by the grain-leaf canopy an average of 7, 26 and 33 percent, respectively. These differences were statistically significant and were relatively constant in the three trials.

The results presented in Table 4 show that spraying with 2,4–D when the grain was 6 to 12 inches tall was less damaging to the alfalfa seedlings than were applications made when the grain was 18 inches tall in 1952 but more damaging in the 2 trials in 1953. In 1952 the plots treated at the 6-inch stage retained 63 percent of the alfalfa stands present on the untreated check plots. Plots treated at the 18-inch stage maintained only 14 percent of the check stands. In 1953 plots treated at the 6-inch stage had stands averaging 33 percent of check while those treated at the 12- and 18-inch stages averaged 47 and 75 percent of check, respectively.

In 1952 there appeared to be an inverse relationship between the amount of spray solution reaching the legume and the survival of

Table 3. Reductions in 2,4–D spray application at alfalfa leaf level due to interception by oat-leaf canopy at 3 stages of growth.

Oat height inches	Appl. lb/A	Application reduction at legume level—pct.			
		1952	1953 I	1953 II	Ave. reduction
6	1.00	2.0	9.6	8.3	
	0.50	0.0	8.1	9.8	
	0.25	4.0	7.4	10.4	
Ave.		2.0	8.3	9.5	6.6
12	1.00	33.3	33.3	25.7	
	0.50	22.0	19.4	14.5	
	0.25	30.8	26.6	30.0	
Ave.		28.7	26.4	23.4	26.2
18	1.00	33.7	32.1	33.7	
	0.50	36.5	23.9	30.3	
	0.25	38.5	32.1	33.0	
Ave.		36.2	29.4	32.3	32.6

Table 4. Alfalfa stands resulting from treating plots with a companion crop at 3 heights using 3 rates of 2,4–D.

Oat height inches	Appl. lb/A	Alfalfa stand—pct. check				
		1952	1953 I	1953 II	Height ave.	Appl. ave.
6	1.00	33.1	4.5	13.2		27.5
	0.50	76.1	44.4	37.4		53.7
	0.25	79.6	54.5	45.8		67.9
Ave.		62.9	34.5	32.1	43.2	
12	1.00	26.8	27.2	16.4		
	0.50	62.0	60.0	45.0		
	0.25	93.0	70.2	62.4		
Ave.		60.6	52.5	41.3	51.5	
18	1.00	3.5	62.4	60.0		
	0.50	9.2	78.6	71.0		
	0.25	30.3	91.3	83.9		
Ave.		14.3	77.4	71.6	54.4	
Check stand-plants/2 sq. ft.		14.2	25.7	25.2		

the seedlings as reflected in stand counts. Applications made at the 6-inch stage of grain allowed a better stand of alfalfa plants than treatment at the 18-inch stage, notwithstanding a reduction of only 2 percent of the spray material at the 6-inch stage in contrast to a reduction of 36 percent at the 18-inch stage.

The climatic conditions at the time of experimentation in 1952 favored a thick, well-tillered stand of oats. Alfalfa seedlings growing in this stand were tall, weak in structure, and easily wet by the spray solutions. The increased wettability of the alfalfa leaves at the later application dates apparently become more important than the reduction in 2,4–D application. Such a response would be in accord with those reported in an earlier paper (2). There is also a possibility

that the dense growth of oats in 1952 handicapped more severely the recovery of the alfalfa plants affected by the 2,4–D application than was the case in 1953.

The data suggest that the factor of light is important in maintaining legumes on areas treated with 2,4–D through its influence on the development and competitive ability of the seedling, and through its ability to modify the wetting capacity of the alfalfa leaves.

In the 1953 trials the stand of oats was much less dense and a more normal growth of legumes resulted. This is indicated by the stands of alfalfa on the check plots which averaged 25.7 and 25.2 plants per 2 sq. ft. in 1953 while only 14.2 plants were obtained in 1952. Under the conditions prevalent in 1953 the interception of the spray was probably the primary factor affecting the stands of alfalfa. Since more spray was intercepted at the 12- and 18-inch growth stage, better stands of alfalfa resulted.

As was noted in the spray volume study, increasing the rates of 2,4–D application reduced the stands of alfalfa. The average stand resulting from the 1.0 and 0.25 lb/A applications were approximately 28 and 68 percent of check respectively.

SUMMARY

1. Studies were conducted to determine the influence of spray volume and height of oats at time of treatment on the amount of 2,4–D reaching the level of the underseeded alfalfa and the effect of these applications on alfalfa stands.

2. The volume of spray used to apply 2,4–D influenced the penetration of the spray through the grain canopy. High spray volumes were found to penetrate oat leaf canopies more effectively than low spray volumes.

3. Notwithstanding the greater degree of penetration by high spray volumes, the toxic effect produced by 2,4–D on alfalfa was reduced, probably as a result of poorer wetting qualities in comparison with low spray volumes.

4. Interception of sprays by oat-leaf canopies increased from the 6- through the 18-inch leaf stages. As much as one-third to one-half of the spray was intercepted prior to reaching the legume level when the grain was 18 inches tall at time of treatment.

5. Application of 2,4–D to oat plots containing an alfalfa seeding, at varying heights of grain, indicated that the ultimate survival of the legume seedlings was a function of morphological development of the legumes at the time of chemical treatment, as well as a manifestation of the protection afforded them by the grain canopy.

6. In general, it appears that the least reduction in stands of alfalfa from applications of 2,4–D will result when stands of oats sown with this legume are about 12 inches tall at time of treatment. At this time a leaf canopy has developed which will reduce the spray application appreciably but the legume seedlings will not have been subjected to sufficient shading to increase leaf wettability or to reduce the vigor of the seedlings.

7. The application of 0.25 lb/A of an amine salt of 2,4–D under favorable conditions reduced alfalfa stands to about two-thirds that of the untreated check plots. Application of 0.5 and 1.0 lb/A of 2,4–D frequently reduced the stands drastically.

8. Stands of alfalfa remaining after treatment with 2,4–D varied widely depending on the combination of the many conditions prevalent at time of and following the application of the herbicides.

LITERATURE CITED

1. CHURCHILL, B. R., and GRIGSBY, B. H. Effects of herbicides upon legume seedlings. NCWCC Res. Rept. p. 110. 1950.
2. DORSCHNER, K. P., and BUCHHOLTZ, K. P. Wetting ability of aqueous herbicidal sprays as a factor influencing stands of alfalfa seedlings. Agron. Jour. 48:59–63. 1956.
3. ———, and ———. A spectrophotometric method for the determination of several chlorinated phenoxyacetic plant growth-regulators. Weeds 5:102–107. 1957.
4. MILLER, J. H., and DUNHAM, R. S. The effect of herbicides on legumes sown with oats. NCWCC Res. Rept. p. 77. 1951.
5. ———, and ———. The effect of herbicides on legumes sown with flax. NCWCC Res. Rept. p. 76. 1951.
6. SMITH, H. H. Quantitative aspects of aqueous spray applications of 2,4–D acid for herbicidal purposes. Bot. Gaz. 107:544–551. 1946.
7. WILLARD, C. J., and BERNARD, R. L. Yields of alfalfa-clover mixtures sown in 2,4–D treated oats. NCWCC Res. Rept. p. 79. 1951.

The Effects of Wind on Delivery Patterns of Nozzles Used for Weed Spraying[1]

M. J. Morgan, L. W. Rasmussen, and L. W. Orton[2]

Growth regulating type herbicides have been found to be effective when applied in low volume sprays. Uniformity of spray application has become a paramount requirement because of the high concentration of the spray solution. Volumes of one to ten gallons of solution per acre are not uncommon. Low volume application requires good design, construction, and operation of equipment. Air movement, temperature, and humidity also influence the spray deposition.

Air movement is seldom, if ever, absent. Even in still atmosphere, the forward movement of spraying equipment creates turbulence of the air. In many instances plants that are sensitive to herbicides have been injured by spray particles which drifted considerable distances from the operating equipment. Even within the treated fields injury to crop plants, or conversely, inadequate control of weeds, has been attributed to uneven distribution caused by air turbulence. Since little information was available on the effect of wind on delivery patterns of nozzles, a study was undertaken to determine the amount of spray deposited at various distances from nozzles with several operating pressures and wind velocities perpendicular to the fan of the nozzles.

Weed spray nozzles of the flat fan type generally produce a spray angle of 60 to 90 degrees. Several investigators have reported (1, 3, 5, 7) that the fan angle or width of coverage, within limits, increased with an increase of pressure. At low pressures the surface tension tends to draw the ends of the fan together and a narrower spray angle is produced. It has been noted by Page (6) that pressure changes modify the spray pattern angle of low discharge nozzles more than that of the larger volume nozzles.

It has been found by Smith (9) that any given nozzle does not produce droplets of only one size but rather produces a continuous range of sizes. High discharge (0.3 to 0.6 gpm) nozzles produce a wider range of sizes than do low discharge (0.03 to 0.1 gpm) nozzles. As orifice size increases, the average droplet size increases, but the small droplets typical of small orifice delivery are not eliminated. Akesson and Harvey (1) and French (4) showed that with a given nozzle the range of droplet size narrowed and the number of small droplets increased as pressure increased.

---

[1]Scientific Paper No. 1548. Washington Agri. Exp. Stations. Work conducted under project No. 836.

[2]Asst. Prof. and Asst. Agricultural Engineer, Dept. of Agricultural Engineering, Agronomist and Asst. Director, Agricultural Experiment Stations, and formerly Res. Asst., Agronomy Dept., respectively, State College of Washington, Pullman.

METHODS AND MATERIALS

The equipment used in the study is shown in Figure 1. The main body of the tunnel was 32 feet long and 4 feet square. The motor and propeller housing at the exhaust end of the tunnel increased the overall length to 36 feet. The tunnel was constructed of ¼-inch Douglas fir plywood and dimension lumber. Honeycomb baffles were secured in each end of the tunnel to reduce turbulence and to produce as nearly as possible a uniform flow of air. A wooden propeller, 4 feet in length, was directly driven by a 5-hp, 1750 rpm electric motor. This furnished the air movement through the tunnel. Air velocity was controlled by two manually operated sliding plywood gates carried in channels at the exhaust end of the motor housing. Settings of these gates were determined for air velocities of 2, 6.5, and 13.5 miles per hour, as measured with a velometer. Velometer readings were taken at various points in the cross section to obtain average velocities in the tunnel.

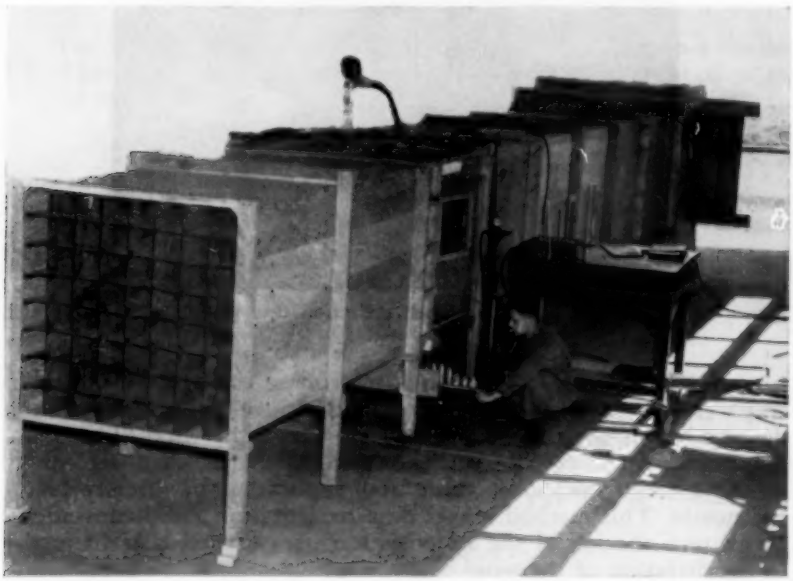


Figure 1. General view of wind tunnel; intake end in foreground.

The test section (Figure 2) was located about 9 feet from the intake end of the tunnel. This section included an access door, a water pipe with connection for one nozzle, necessary valves and switches, and two interchangeable collection trays as described by Barger et al. (2). The trays were made of galvanized iron with corrugations 2⅜ inches on centers. Spray deposited in each corrugation was collected and measured volumetrically. In Position 2, a collection tray with corrugations placed longitudinally in the tunnel was used to measure

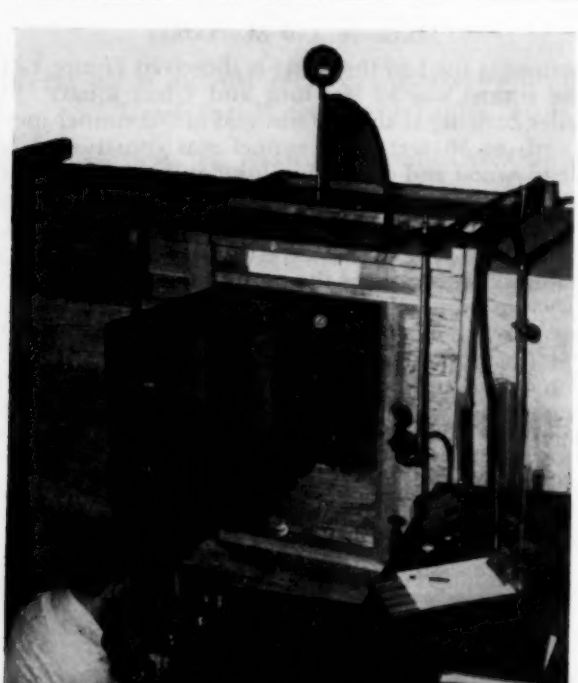


Figure 2. View of test end stand with collection tray installed for Position 2.

spray fan distortion. In Position 1, the corrugations of the collection tray were placed at right angles to the air movement to measure the down wind displacement of the spray pattern by wind. The quantities of water at each corrugation were calculated as a percentage of the average mid-point value at 0 mph; that is, directly below the nozzle. This method makes data presentation more convenient. In all tests the fan of the spray pattern was turned at right angles to the direction of the wind.

Spray drift potential was also measured by use of stainless steel plates positioned at intervals on the floor of the tunnel down wind from the nozzles. Four of these (1 by 3 inch) stainless steel plates were placed equidistant across the floor of the tunnel at each location 10, 14, 18 and 22 feet down wind from the test nozzles. A water soluble dye, pontamine blue, was used in a known concentration in water for these tests. After each test at a given pressure and wind velocity, the dye solution was washed from the plates and made to a standard volume. Measurement with an Evelyn photoelectric colorimeter gave relative density values for the spray collected. Within the range used, the density values obtained were essentially linear

Table 1. A comparison of the nozzles used showing the nozzle angle, the manufacturer's rating and the calibrated rating in gallons per hour at 30 pounds per square inch and at 0 mph wind.

Nozzle brand	Nozzle number	Manufacturer's rating gal/hr	Calibrated rating gal/hr	Nozzle angle degrees
A	59	27.0	25.5	70
	32	7.2	6.7	70
	22	3.5	3.6	70
B	600	31.2	29.7	65
	150	7.8	8.3	65
	067	3.6	3.8	65

with concentration. A comparison of the nozzles used are shown in Table 1. The nozzles of each size were selected at random. The sizes were chosen as representative of the sizes used for application of growth-regulating herbicides.

RESULTS

The results of the tests are shown graphically in Figures 3 through 9. These were plotted for each 2⅜ inches by using volume of material collected. The distance along the abscissa is shown in even two

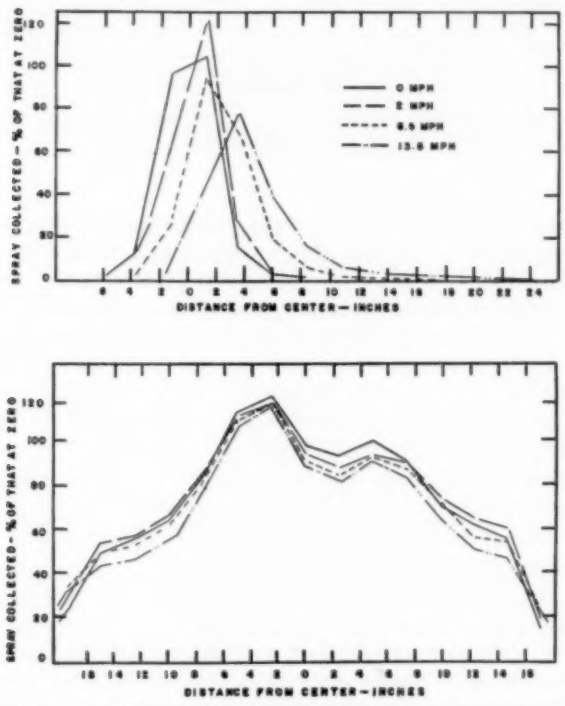

SPRAY COLLECTED - % OF THAT AT ZERO
0 MPH
2 MPH
8.5 MPH
13.8 MPH
DISTANCE FROM CENTER - INCHES
SPRAY COLLECTED - % OF THAT AT ZERO
DISTANCE FROM CENTER - INCHES

Figure 3. Effects of different wind velocities on the spray patterns of nozzle 59 at 30 psi. Above, Position 1; below, Position 2.

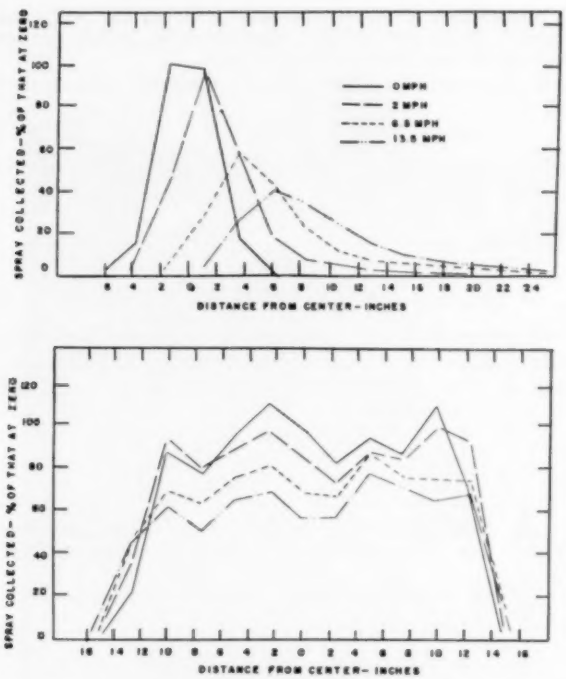


Figure 4. Effects of different wind velocities on the spray pattern of nozzle 32 at 30 psi. Above, Position 1; below, Position 2.

inch increments although the data were plotted for each 2⅜ inches. The experiment was designed and analyzed as a factorial with two replicates.

The data obtained from Position 1 tests show the total displacement of the spray measured to a distance 26 inches down wind from the nozzles; collection was made at right angles to the wind.

A comparison of Figure 5, Position 1 and Figure 6, Position 1 show the relative drift effect on the smallest and largest nozzles tested at a pressure of 30 psi. Figure 8, Position 1 and Figure 9, Position 1 show a comparison of spray displacement when the smallest nozzles of brand B were tested at two different pressures. It is apparent that an increase in pressure caused an increase in the amount of drift, especially when small nozzles were tested.

For each nozzle, the amount of spray carried down wind beyond the collection tray was calculated by differences and converted to a percentage of the total collected at zero wind. Nozzles 067 and 600, the smallest and the largest nozzles of brand B, will serve as an example of the results of the tests run at 30 psi. With number 067, the smaller of the two nozzles, the percentage losses at air velocities

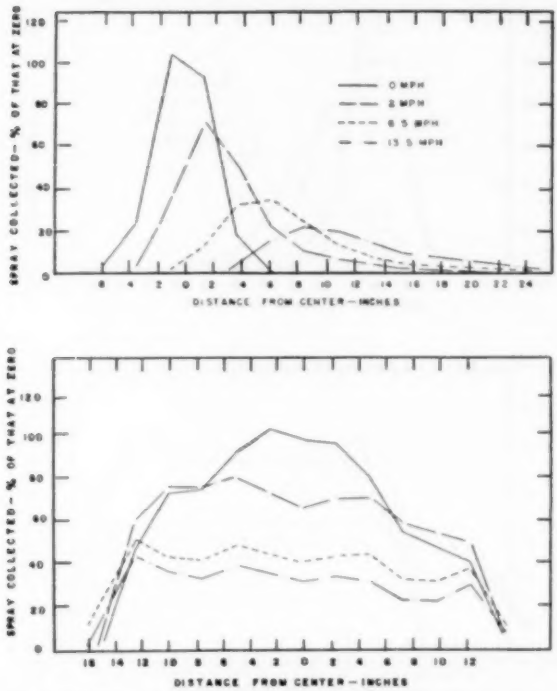

SPRAY COLLECTED — % OF THAT AT ZERO
0 MPH
2 MPH
6.5 MPH
13.5 MPH
DISTANCE FROM CENTER — INCHES
SPRAY COLLECTED — % OF THAT AT ZERO
DISTANCE FROM CENTER — INCHES

Figure 5. Effects of different wind velocities on the spray pattern of nozzle 22 at 30 psi. Above, Position 1; below, Position 2.

of 2, 6.5 and 13.5 mph were 5.5, 16.7 and 29.4, respectively. The same tests with nozzle 600 showed 0.6, 1.2 and 3.1 percentage losses over the same air velocities. An increase in wind had a relatively greater effect on drift of the low discharge nozzle. As will be shown later, this does not necessarily mean a greater total amount of drift with the low discharge nozzle.

Position 2 of each figure shows the distribution patterns of each nozzle at zero wind velocity and also the distortion of the pattern by increasing wind velocities. In these tests, collection was made parallel to the wind. At zero wind, few of the patterns approached symmetry or the idealized pattern of gradually decreasing volume of spray at the ends. Some of the patterns showed erratic variations in volume of spray from end to end (Figure 4, Position 2.)

Increasing air velocity produced an effect which was characteristic of all nozzles tested. The center of the spray pattern was blown out in varying degrees of severity but the ends remained rather constant or even increased in volume (Position 2, Figures 3, 4, 5, 6, 7, 8, 9). This indicates that relatively large droplets were concentrated at ends of the elliptical spray patterns produced by the nozzles. The patterns of low discharge nozzles were altered to a greater extent by

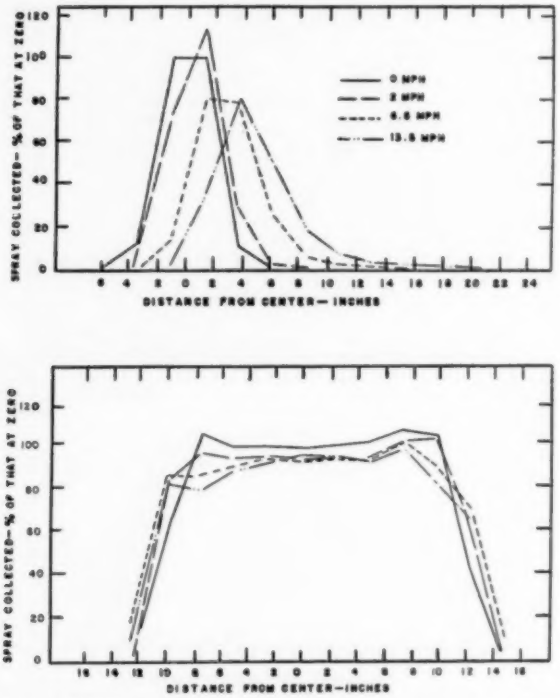


Figure 6. Effects of different wind velocities on the spray pattern of nozzle 600 at 30 psi. Above, Position 1; below, Position 2.

an increase in wind than the patterns of high discharge nozzles. This is illustrated rather effectively in Position 2, Figures 3 and 5. The pattern of number 59, a high discharge nozzle of brand A, remained relatively uniform with an increase in wind, although the effect of increased volume at the ends of the pattern appeared here also. The pattern of number 22, a low discharge nozzle of brand A, underwent extreme alteration as the wind velocity was increased.

In another series of tests, using steel plates, differences in relative drift were determined at points beyond the collection tray up to a distance of 22 feet down wind from the nozzle support. The colorimeter density values, used as a measure of spray collected on the plates, were analyzed statistically.

The three variables studied were found to cause highly significant differences in spray drift over the distances measured. Spray drift increased with increased pressure, air velocity, and decrease in nozzle size (Table 2). These effects apparently reflect droplet size relationships. The low discharge nozzles produced a larger proportion of small droplets, while the higher pressure of 45 psi increased the number of small droplets produced by a given nozzle.

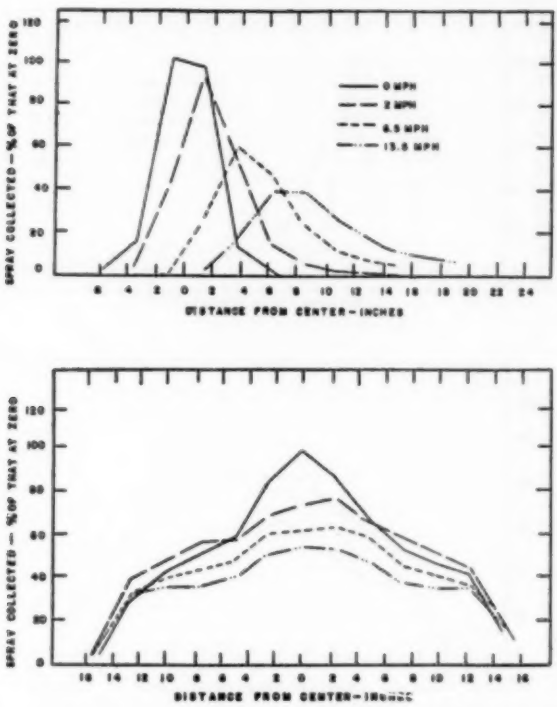

SPRAY COLLECTED — %OF THAT AT ZERO
0 MPH
2 MPH
6.5 MPH
13.5 MPH
DISTANCE FROM CENTER — INCHES
SPRAY COLLECTED — %OF THAT AT ZERO
DISTANCE FROM CENTER — INCHES

Figure 7. Effects of different wind velocities on the spray pattern of nozzle 150 at 30 psi. Above, Position 1; below, Position 2.

Table 2. The effect of wind velocity, nozzle orifice size, and pressure on spray distribution expressed as treatment means.

Nozzle number	Nozzle ave.	Colorimeter density values							
		Wind x nozzle interaction		Pressure x nozzle interaction		Wind x pressure x nozzle interaction			
						6.5 mph		13.5 mph	
		6.5 mph	13.5 mph	30 psi	45 psi	30 psi	45 psi	30 psi	45 psi
59	0.058	0.023	0.094	0.047	0.072	0.020	0.026	0.073	0.115
32	0.071	0.040	0.095	0.064	0.079	0.052	0.043	0.075	0.115
22	0.075	0.066	0.084	0.078	0.082	0.064	0.068	0.071	0.096
067	0.071	0.048	0.093	0.061	0.080	0.041	0.056	0.081	0.104
150	0.067	0.039	0.096	0.065	0.070	0.041	0.037	0.089	0.103
600	0.047	0.018	0.076	0.048	0.048	0.017	0.019	0.076	0.076
Mean		0.040	0.090	0.058	0.072	0.039	0.042	0.077	0.102

The treatment means of the wind x pressure interaction, as shown in Table 2, indicate that at the low wind velocity of 6.5 mph the change in pressure caused only minor differences in tendency to drift. However, at the higher wind velocity of 13.5 mph drift increased greatly when pressure was increased from 30 to 45 psi.

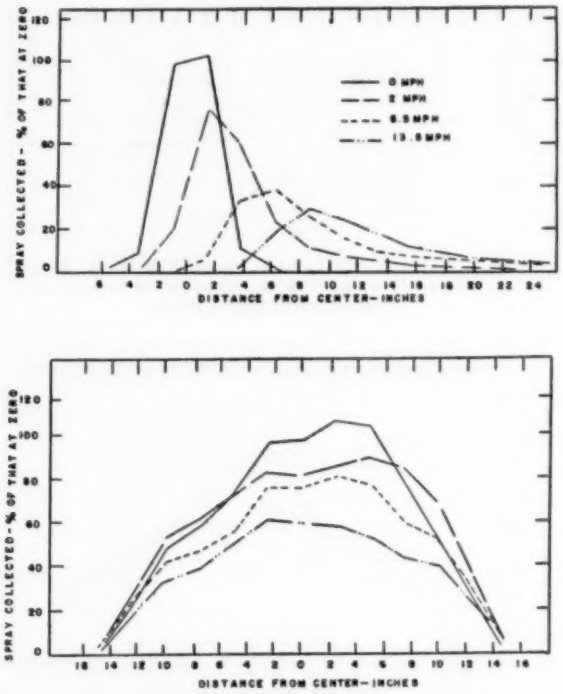


Figure 8. Effects of different wind velocities on the spray pattern of nozzle 067 at 30 psi. Above, Position 1; below, Position 2.

The wind x nozzle interaction is especially interesting because it contradicts the common assumption that drifting of spray materials can be reduced by using nozzles with large orifices. It was found that this assumption holds true with the lower wind velocity of 6.5 mph but not with the higher wind. At 13.5 mph with brand A there was an increase in drift from the high discharge nozzle as compared with the low discharge nozzle of that brand. With brand B the same comparison showed a small decrease in drift. At the lower wind velocity (6.5 mph) the drift from each of the two low discharge nozzles of the two brands was approximately triple that of the high discharge nozzles.

The wind x distance interaction was also highly significant, indicating a differential effect of the two wind velocities over the four distances. The treatment means in Table 3 show that a proportionately greater amount of spray was deposited at the 22-foot position with the higher wind velocity of 13.5 mph. This was almost one fourth the amount collected at the 10-foot point. The same comparison at the lower wind velocity reveals that the amount collected at the 22-foot distance was somewhat less than one sixth the amount collected at the 10-foot distance.

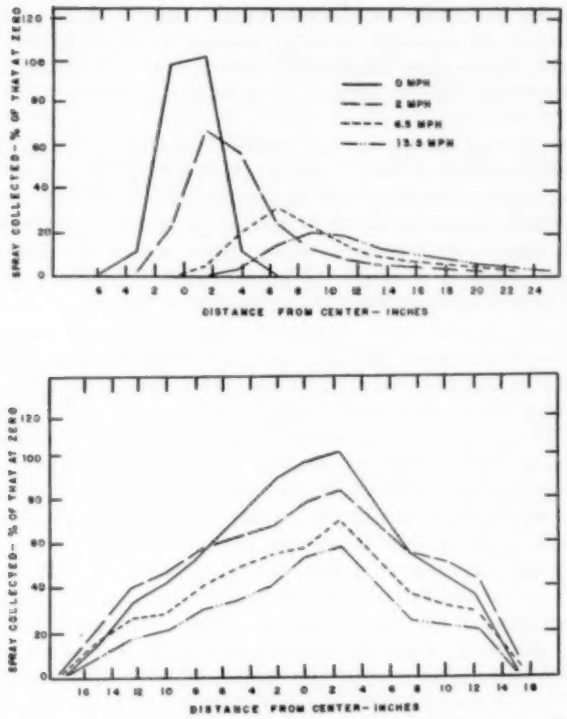


Figure 9. Effects of different wind velocities on the spray pattern of nozzle 067 at 45 psi. Above, Position 1; below, Position 2.

Table 3. The effect of wind velocity, distance, and pressure on spray distribution expressed as treatment means for all nozzles.

Collection distance feet	Distance ave.	Colorimeter density values							
		Wind x distance interaction		Pressure x distance interaction		Wind x pressure x distance interaction			
						6.5 mph		13.5 mph	
		6.5 mph	13.5 mph	30 psi	45 psi	30 psi	45 psi	30 psi	45 psi
10	0.123	0.088	0.157	0.112	0.133	0.088	0.088	0.137	0.178
14	0.069	0.039	0.099	0.061	0.076	0.036	0.040	0.086	0.112
18	0.039	0.020	0.058	0.035	0.044	0.019	0.022	0.051	0.066
22	0.029	0.014	0.043	0.025	0.032	0.013	0.015	0.036	0.049

DISCUSSION

The discovery and development of chemicals toxic to weeds in minute amounts has encouraged the use of low-volume applications of herbicides. Such spray applications require nozzles of small orifice size which unavoidably produce numerous small droplets and aggravate the problem of drift of spray material by wind. It has been commonly accepted that the use of high discharge nozzles for spray-

ing herbicides in windy conditions would reduce drift and decrease the probability of damage to neighboring fields of plants sensitive to herbicides. At higher wind velocities there is little advantage in using nozzles with larger orifices in an effort to reduce drift of spray materials.

However, it was shown in this study that with a wind velocity of 13.5 mph the volume of drift from high discharge and low discharge nozzles was approximately the same. Shanks and Peterson (8) and Smith (9) have shown that high discharge nozzles produce a range of droplet sizes comparable to those from small discharge nozzles. In addition there is a range of larger sizes produced. Apparently the total volume of droplets of a certain size range acted upon by a wind velocity of 13.5 mph does not vary greatly in patterns from nozzles of various sizes. When low discharge nozzles are used in field spraying, higher concentrations of herbicides are ordinarily required and there is greater danger of crop injury from drifting material. There is no reason to believe, however, that drifting droplets from high discharge nozzles are of such low concentration that there is no possibility of damaging plants sensitive to herbicides.

In the calibration of nozzles under no-wind conditions for use in this study considerable variations in delivery rates were observed. The use of such nozzles in actual spraying would result in an excess or a deficiency of the calculated amount of herbicide. The noticeable lack of symmetry of the spray patterns could also cause uneven applications in the field. Spacing nozzles along the boom to get double coverage of the spray materials might smooth out some of these irregularities, although the distribution would not be completely uniform. The condition could be somewhat alleviated by rotating a nozzle 180 degrees where excessive volume of spray material is found midway between two adjacent nozzles.

Several investigators have reported an increase in fan width of spray patterns by increased pressures (1, 2, 3, 6, 9). In this study a slight increase in fan width for some of the nozzles was observed but the changes were neither uniform nor consistent. Often the increase in width was not symmetrical. However, the method of collecting spray in the corrugated trays did not permit accurate measurement of small differences at the ends of the spray pattern, so differences of less than two per cent were not considered. An increase in length of test run would have given a better measure of changes in fan width, but this was not feasible with the size of containers used for collection across the center of the nozzle pattern.

SUMMARY

1. Tests were run in a wind tunnel on six fan-type weed spray nozzles of various sizes to determine the effect of wind on the spray pattern at pressures of 30 psi and 45 psi. The air velocities selected were 0, 2, 6.5, and 13.5 mph. Total displacement and relative distortion of the spray patterns were measured by collecting the spray on corrugated trays. Measures of drift beyond the corrugated trays

were made by collecting spray on small steel plates placed on the floor of the tunnel.

2. Nozzle patterns in still air differed greatly. Some nozzles delivered a large volume at the center of the pattern. Some delivered the greatest volume away from the center of the pattern, and others produced unsymmetrical patterns.

3. It was found that spray patterns of small orifice nozzles were more subject to drift than patterns from the high discharge nozzles. Increased pressure caused greater drift with all nozzles tested.

4. There was less spray drift, on a volume basis, from high discharge nozzles than from low discharge nozzles at 6.5 mph; and at 13.5 mph, there was about the same amount of drift from both sizes of nozzles.

5. The drift effect of wind was greater at the centers than at the ends of the spray patterns of all nozzles tested. Apparently there was a greater proportion of large droplets at the ends of the patterns.

6. An increase in pressure from 30 to 45 psi produced a differential response in spray drift with a change in air velocity. A negligible difference in drift was produced at the two different pressures at the lower air velocity of 6.5 mph. The drift of spray material at 45 psi was significantly greater than the drift at 30 psi at an air velocity of 13.5 mph.

ACKNOWLEDGEMENT

The laboratory work was under the supervision of W. H. Johnson, formerly Asst. Prof. of Agricultural Engineering, State College of Washington, Pullman.

LITERATURE CITED

1. AKESSON, N. B., and HARVEY, W. A. Equipment for the application of herbicides. Ag. Eng. 29:384–389. 1948.
2. ———, and ———. Chemical weed-control equipment. Calif. Agr. Exp. Sta. Cir. 389. 1948.
3. BARGER, E. L., COLLINS, E. V., NORTON, R. A., and LILJEDAHL, J. B. Problems in the design of chemical weed control equipment for row crops. Ag. Eng. 28:381–383. 1948.
4. FRENCH, ORVAL C. Machinery for applying atomized oil spray. Ag. Eng. 15:324–336. 1934.
5. ———, and CRAFTS, A. S. Characteristics of spray nozzles for vegetables and weed spraying. Ag. Eng. 17:115–119. 1936.
6. PAGE, G. E. Weed spraying equipment. Oreg. Agr. Expt. Sta. Bul. 493. 1951.
7. PRICE, F. E., LUNDE, R. N., BURSIK, JOHN, and FREED, VIRGIL. Recommendations for weed spraying equipment. Oreg. Agr. Expt. Sta. Circ. 170. 1946.
8. SHANKS, G. L., and PETERSON, J. J. Technique for spray nozzle testing. Ag. Eng. 29: 539–540. 1948.
9. SMITH, H. H. Quantitative aspects of aqueous-spray applications of 2,4–dichlorophenoxyacetic acid for herbicidal purposes. Bot. Gaz. 107:544–551. 1946.

Pre-Emergence Weed Control in Soybeans[1]

HENRY W. INDYK[2]

ONE of the major problems in present-day soybean production is weed control. The increased interest in profitable soybean production in recent years has stimulated a demand for a satisfactory and economical means of chemical control to supplement cultural practices. The gradual shift from solid planting to row planting has practically eliminated the problem of weeds between rows, but it has not solved the critical problem of weed growth in the row.

Weed infestations, in the row, which survived cultivation were found to reduce soybean yields approximately 10 percent (9). Weeds not only compete with the soybeans for nutrients, moisture, and light, but also interfere with harvesting operations and may lower the quality of the soybean seed. Soybeans are excellent weed competitors after they become well established and when environmental conditions are favorable for rapid growth. However, their competitive efficiency is at a minimum from the time of planting to the time the soybean plants form a dense vegetative cover. An economical and reliable means of chemical control of weeds, particularly during this critical 4 to 6 week period, would be desirable for supplementing present means of cultural control. Because of the sensitivity of the soybean plant to present day herbicides, it appears that pre-emergence chemical treatments would be more promising than post-emergence treatments.

In order to receive wide acceptance under Delaware conditions, the herbicide must be satisfactory for use on the light textured soils which are predominant in the soybean producing areas of the state. Among the most troublesome weeds are pigweed *(Amaranthus retroflexus)*, lamb's quarters *(Chenopodium album)*, ragweed *(Ambrosia artemisiifolia)*, morning glory *(Ipomea spp.)* and crabgrass *(Digitaria spp.)*. This paper is a summary of the performance of various herbicides evaluated as pre-emergence treatments on soybeans during the three-year period, 1954 to 1956 inclusive.

LITERATURE REVIEW

Considerable attention by many investigators has been devoted to chemical control of weeds in soybeans. However, progress has been comparatively slow. The limited number of recommendations for chemical control of weeds in soybeans at present are not receiving very wide or rapid acceptance for practical application in their respective areas of adaptation because of the varied results and cost of treatment.

The most promising results from pre-emergence chemical treatments appear to be centered primarily upon DNBP (4,6–dinitro ortho secondary butylphenol) and CIPC (isopropyl N–(3–chloro-

[1]Misc. Paper No. 259, Delaware Agri. Exp. Sta., Newark.

[2]Assistant Professor, Department of Agronomy and Agricultural Engineering.

phenyl)carbamate) and to some extent upon NPA (N–1–naphthyl phthalamic acid), NaPCP (sodium pentachlorophenate), and 2,4–D (2,4–dichlorophenoxyacetic acid) (2, 3, 4, 5, 6, 8, 10, 11, 12, 13). Previous work in Delaware conducted by Springer[3] indicated NPA and 2,4–D to be superior to other herbicides which were evaluated.

In summarizing some of the suggested practices of the various weed conferences, a U.S.D.A. report specified CIPC or DNBP at 4 to 8 pounds in 10 to 20 gallons of water per acre for pre-emergence application for the control of annual weeds in soybeans (1). The report further states that "if heavy rains follow application and prior to crop emergence, treatment may injure beans; if prolonged drought follows application, weed control may be erratic. DNBP compounds produce vapors toxic to soybean seedlings if temperatures of 88° F or higher prevail for 5 to 10 continuous days when soybeans are emerging. Temperatures of 90° F or higher cause rapid evaporation of both CIPC and DNBP and may greatly reduce their period of effective weed control."

A chemical which is showing considerable promise for grass control in the midwest is CDAA (2–chloro–N,N–diallylacetamide). Two years of research indicate it to be affected less by varied weather conditions than other herbicides (7). In addition, the soybean seedlings appear to have a high degree of tolerance to this chemical.

MATERIALS AND METHODS

Numerous herbicides were evaluated as pre-emergence treatments on soybeans at two locations in Delaware. The soil type represented at the southern location (Georgetown) in 1954 and 1956 was a Norfolk loamy sand and at the northern location (Newark) in 1954, 1955, and 1956 a Sassafras loam. The 1955 test at Georgetown was abandoned because of: (1) an uneven stand of soybeans as a result of an infestation of corn seed maggot and (2) an abnormally high nutgrass population which predominated.

The herbicides which were included in these studies were as follows: 2,4–dichlorophenoxyacetic acid, triethanolamine (2,4–D amine); butanediol ester of 2,4–D (2,4–D butanediol ester); isopropyl ester of 2,4–D (2,4–D isopropyl ester); 2,4–D acetamide (Emid); 2–(2,4,5–trichlorophenoxy) propionic acid, amine [2–(2,4,5–TP)A]; the propylene glycol butyl ether ester of 2,4,5–T propionic [2–(2,4,5–TP)E]; 2–methyl–4–chlorophenoxy–n–butyric acid (4–MCPB); sodium pentachlorophenate (NaPCP); pentachlorophenol (PCP); 4,6–dinitro ortho secondary butylphenol, alkanolamine salt (DNBP); N–1–naphthyl phthalamic acid (NPA); sodium salt of NPA (NaNPA); 2–chloro–N,N–diethylacetamide (CDEA); 2–chloro–N,N–diallylacetamide (CDAA); 2–chloroallyl diethyldithiocarbamate (CDEC); isopropyl N–(3–chlorophenyl) carbamate (CIPC); (1–chloropropyl–2)N–(3–chlorophenyl)carbamate (CPPC); sec.–butyl N–(3–chlorophenyl)carbamate (BCPC); 3–(*p*–chlorophenyl)–1,1–di-

[3]Springer, F. B. Pre-emergence chemical weed control in soybeans. M. S. thesis, University of Delaware. 1954.

methylurea (monuron); 3–(3,4–dichlorophenyl)–1,1–dimethylurea (diuron); 3–(3,4–dichlorophenyl)–1–methyl–1–*n*–butylurea (neburon); sodium 2,4,5–trichlorophenoxyethyl sulfate (2,4,5–TES); sodium 2,4–dichlorophenoxyethyl benzoate (2,4–DEB); disodium 3,6–endoxohexahydrophthalate (endothal); 3–amino–1,2,4–triazole (ATA); and 2,4–dichlorophenoxyethyl phosphite (3Y9). The rates of application, years evaluated, and locations at which evaluated are indicated in Tables 1, 2, and 3.

Wabash soybeans were seeded in rows at a depth of approximately 1.5 inches and at the rate of 40 pounds of seed per acre. Seeding dates at Georgetown were June 2 and 12 for 1954 and 1956 respectively; at Newark, June 9, 6, and 8 for 1954, 1955, and 1956 respectively. Individual plots consisted of 4 rows with each row 18 feet long and spaced 3 feet apart. Each herbicide at the specified rates was applied over the entire area of its respective plot using a garden tractor-mounted sprayer at a pressure of 30 psi. The low rate of each herbicide was applied in solution at the rate of 25 gallons per acre. The double rate of each herbicide was applied by spraying the respective plots twice using the single rate calibration on the sprayer. All treatments were replicated in triplicate.

Two check plots were maintained, one of which received the same cultivation treatment as the chemically treated plots (designated as the check treatment). The other check received cultivation as needed, commencing at the time of seeding and continuing throughout the growing season (designated as the check-cultivated treatment). The latter check treatment generally required two cultivations during the initial 35-day period before all plots were cultivated.

The performance of the herbicides was evaluated on the basis of suppression of weed growth and the effect on soybean stand and yield. Weed control, determined by visual estimates of broadleaves and grasses individually, was rated from 0 to 10; 0 representing no weed control and 10 perfect control. Weed control ratings and soybean stand counts were taken 35 days after application of chemical treatments. Soybean stand counts were taken from 12.5 feet of each of the two center rows in each plot and expressed as percentage stand reduction on the basis of the plot indicated as check. During the remainder of the growing season, all plots were cultivated as needed to control emerging weeds in all tests with the exception of the 1954 test at Newark. In this test, the chemically treated plots and check received no cultivation for the entire season. The check-cultivated plot was cultivated as required during the entire season for cultural control of weeds. Soybean yield data were determined from samples harvested from 12.5 feet of each of the two center rows of each plot.

RESULTS AND DISCUSSION

1954. The performance of the herbicides evaluated in 1954 at Georgetown and Newark is summarized in Table 1. At Georgetown, soil moisture at the time of planting soybeans was satisfactory for good soybean and weed germination. During the 35-day period

Table 1. The effect of pre-emergence herbicides on weed control, soybean stand, and soybean yield at the indicated locations in 1954.

Treatment	Rate lbs/A	Georgetown			Newark			
		Weed control rating[a]		Soybean stand reduction %	Soybean yield bu/A	Weed control rating[a]	Soybean stand reduction %	Soybean yield bu/A
		Broadleaves	Grasses			Broadleaves		
2,4-D amine	1	7.5	6.5	6.0	20.5	6.1	0.0	17.3
2,4-D amine	2	8.5	6.3	14.0	17.9	7.8	0.0	22.4
2,4-D butanediol ester	0.5	4.7	5.4	8.0	26.3	0.0	2.4	10.9
2,4-D butanediol ester	1	6.5	6.2	10.0	25.7	5.0	12.2	15.4
2 (2,4,5-TP)A	1	7.5	5.7	13.3	29.5	2.7	1.2	15.8
2 (2,4,5-TP)A	2	8.4	5.3	14.7	27.6	5.0	8.5	14.3
2 (2,4,5-TP)E	1	7.4	3.8	0.0	23.7	2.8	4.9	17.8
2 (2,4,5-TP)E	2	8.3	7.4	11.3	19.8	6.1	12.2	17.8
NaPCP	12.5	6.9	2.3	5.3	32.9	1.7	7.3	12.7
NaPCP	25	8.8	7.2	6.0	31.0	2.2	12.2	17.1
DNBP	3	5.8	0.8	0.7	30.4	0.0	0.0	8.9
DNBP	6	8.0	4.5	1.3	29.2	1.1	3.7	8.9
NPA	2	5.7	5.5	5.3	26.0	1.7	0.0	16.3
NPA	4	7.2	6.9	10.0	27.2	3.3	6.1	13.3
CIPC	2	4.6	0.5	6.7	21.6	0.0	1.2	16.0
CIPC	4	6.5	3.5	9.3	21.6	0.0	1.2	17.2
CPPC	2	2.9	1.8	0.0	17.8	0.0	0.0	8.4
CPPC	4	5.6	4.4	6.0	20.5	0.0	0.0	8.0
Monuron	0.5	6.5	4.4	5.3	22.3	0.0	1.2	8.2
Monuron	1	7.6	6.3	8.0	23.7	0.0	13.4	10.2
Diuron	0.5	7.3	4.8	0.7	27.7	1.1	0.0	10.8
Diuron	1	8.5	7.5	10.0	30.0	2.2	12.2	10.2
2,4-DEB	2	7.5	7.8	6.0	21.1	3.9	3.7	19.5
2,4-DEB	4	8.3	7.8	12.7	21.1	5.0	6.1	26.0
2,4,5-TES	2	7.5	7.4	2.0	25.2	3.9	0.0	15.4
2,4,5-TES	4	7.7	7.2	10.7	28.9	6.1	2.4	16.4
Endothal	3	4.5	0.2	2.7	17.5	0.6	0.0	11.3
Endothal	6	5.8	1.4	14.0	15.9	5.0	8.5	12.0
ATA	3	5.0	6.3	25.3	17.1	0.0	0.0	10.7
ATA	6	7.2	6.6	48.7	12.6	0.0	7.3	12.6
NaPCP +2,4-D isopropyl ester[b]	12.5 +1	—	—	—	—	6.1	2.4	27.4
NaPCP +2,4-D isopropyl ester[b]	25 +2	—	—	—	—	8.3	0.0	29.1
Check[c]		0.0	0.0	0.0	19.5	0.0	0.0	12.4
Check-cultivated[d]		8.2	7.4	3.3	24.6	7.2	0.0	26.3
L.S.D. .05					9.3			7.3
.01					12.4			9.7

[a]Weed control rating: 0 = no control, 10 = perfect control. Grass population at Newark very sparse—morning glory predominated.
[b]50–50 oil-water carrier.
[c]Check—received cultivation identical to chemically treated plots.
[d]Check-cultivated—received cultivation as needed, commencing at time of planting.

after planting on June 2, rainfall (inches) was recorded as follows: June 10—.41, 13—.35, 14—.12, 15—.08, and 26—.12; July 2—.01, 4—.21, 5—.63, and 6—.75. Maximum daily temperatures of 85° F or above during this same period were recorded on 22 days, 13 days of which were 90° F or above.

Broadleaf weed growth, predominantly pigweed, lamb's quarters, and ragweed, was very effectively controlled with NaPCP at the rate of 25 lbs. per acre (Table 1). Although somewhat less effective in the control of grasses (predominantly crabgrass) satisfactory results were obtained. Soybean stands were slightly reduced but without a resultant reduction in yield. The yield of 31.0 bu. per acre from the NaPCP treated plot represented a statistically significant increase, approaching the 1 percent level, above the check plot. In comparison

to the check-cultivated plot the yield increase was 6.5 bushels but statistically insignificant.

Included among the remaining chemicals which showed promise in satisfactory weed control without serious soybean yield reductions were diuron at 1 lb. per acre, DNBP at 6 lbs. per acre, 2–(2,4,5–TP)A at 2 lbs. per acre, NPA at 4 lbs. per acre, and 2,4,5–TES at 4 lbs. per acre. 2,4–D amine, 2–(2,4,5–TP)E, monuron, and 2,4–DEB gave satisfactory weed control but reduced soybean yields.

At Newark weather conditions, characterized by abnormally low rainfall and high temperatures, were very unfavorable for both soybean and weed germination. Subsequent to planting soybeans on June 9, soil moisture was deficient. During the 35-day period following planting, rainfall (inches) was recorded as follows: June 14—.25, 15—.10, 17—.09, and 26—.12; July 4—.11, 5—.07, 6—.15, 7—.02, and 9—.41. Maximum daily temperatures of 85° F or above were recorded on 24 days during this same period, 15 days of which were 90° F or above.

The weed population consisted almost exclusively of a heavy infestation of morning glory. Accordingly, the performance of the herbicide treatments was evaluated on the basis of controlling morning glory. The normal procedure of cultivation of all plots after the initial 35-day period was not practiced in this test. Because of the dense and viney growth of morning glory which entangled the soybean plants in the plots where little or no control of morning glory was obtained it was not possible to cultivate without causing serious defoliation of the soybean plants. Consequently, it was decided to eliminate cultivation on all plots excepting the check-cultivated plot.

Excellent control of morning glory was obtained from a mixture of 25 lbs. of NaPCP and 2 lbs. of 2,4–D isopropyl ester per acre emulsified in a 50–50 oil-water carrier. Stoddard solvent was used as the oil component of the oil-water carrier. Stoddard solvent alone was not included in the test but it was applied to border rows of the experimental area. Very little, if any, control of morning glory was noted. It was interesting to note that the NaPCP + 2,4–D mixture gave excellent control of weeds during the entire season even though no means of cultural control was used. The yield of soybeans from the plot treated with this chemical mixture was 29.1 bushels per acre as compared to 26.3 bushels per acre from the check plot which received cultivation throughout the entire season. On the basis of these facts, the question arises as to the usefulness of cultivation for purposes other than weed control.

2,4–DEB at 4 lbs. per acre did not materially reduce the morning glory population but it did produce a stunting effect from which the morning glory did not recover. The application of 2,4–D amine at 2 lbs. per acre also showed some promise in controlling the morning glory but reduced the soybean yield.

1955. No data are presented for the Georgetown location. Previously it was mentioned that this test failed. The results at the Newark location are presented in Table 2.

Table 2. The effect of pre-emergence herbicides on weed control, soybean stand, and soybean yield at Newark in 1955.

Treatment	Rate lbs/A	Weed control rating[a]		Soybean stand reduction %	Soybean yield bu/A
		Broad-leaves	Grasses		
2,4-D amine	1	3.0	0.0	0.7	9.0
2,4-D amine	2	4.3	0.0	22.5	15.7
2-(2,4,5-TP)A	1	6.3	0.0	19.2	7.0
2-(2,4,5-TP)A	2	8.3	2.0	40.0	7.2
NaPCP	12.5	4.0	2.7	0.0	24.6
NaPCP	25	8.0	4.3	2.0	37.0
DNBP	3	2.0	0.0	0.7	17.4
DNBP	6	5.0	2.7	12.6	24.7
NaNPA	2	5.7	4.0	11.3	25.1
NaNPA	4	7.3	6.3	12.6	29.6
CPPC	5	0.0	2.7	0.0	22.8
CPPC	10	1.0	6.3	0.0	29.4
2,4,5-TES	3	4.3	4.3	20.5	19.6
2,4,5-TES	6	7.3	6.3	31.1	23.3
CDAA	5	0.0	0.7	0.0	17.9
CDAA	10	0.7	2.0	0.0	18.3
CDEA	5	0.7	0.0	0.0	8.1
CDEA	10	1.7	1.0	31.1	9.6
CDEC	5	2.0	6.0	0.0	24.5
CDEC	10	6.0	8.0	0.0	31.3
NaPCP+2,4-D isopropyl ester[b]	12.5+1	8.0	4.3	16.6	21.1
NaPCP+2,4-D isopropyl ester[b]	25 +2	8.7	7.7	23.8	26.9
NaPCP+CDEC	10 +5	5.3	4.7	0.0	23.7
NaPCP+CDEC	20 +10	9.0	9.0	0.0	34.2
Check[c]		0.0	0.0	0.0	11.9
Check-cultivated[d]		7.8	7.8	4.6	29.2
L.S.D. .05					9.7
.01					13.0

[a]Weed control rating: 0 = no control, 10 = perfect control.
[b]50-50 oil-water carrier.
[c]Check—received cultivation identical to chemically treated plots.
[d]Check-cultivated—received cultivation as needed, commencing at time of planting.

Soil moisture at Newark on the date of planting, June 6, was deficient. During the following 35-day period, above normal rainfall (inches) was recorded as follows: June 8—1.05, 9—1.83, 11—.88, 12—.50, 13—.03, 19—.70, 20—.18, 23—.55, 24—.07, and 25—1.05; July 10—.04. Maximum daily temperatures of 85° F or above during this same period were recorded for 19 days, 8 days of which were 90° F or above.

The heavy weed infestation was predominantly pigweed, lamb's quarters, and crabgrass. The results in Table 2 indicate very good broadleaf control from NaPCP at 25 lbs. per acre. The yield of 37.0 bu. per acre was 7.2 bushels higher than the check-cultivated plot. Grass control was poor. Very good control of grasses and fair control of broadleaves was obtained with CDEC at 10 lbs. per acre. In the control of both broadleaves and grasses without any reduction in soybean yield, a mixture of NaPCP and CDEC at 20 and 10 lbs. per acre, respectively, was superior to all treatments included in this study. Similar to the 1954 results, the NaPCP and 2,4-D mixture at the high rate resulted in very good weed control.

Among the remaining treatments, NaNPA at 4 lbs. per acre showed most promise. 2-(2,4,5-TP)A at 2 lbs. per acre produced good control of weeds but seriously reduced the soybean stand and

Table 3. The effect of pre-emergence herbicides on weed control, soybean stand, and soybean yield at the indicated locations in 1956.

Treatment	Rate lbs/A	Georgetown			Newark			
		Weed control rating[a]	Soybean stand reduction %	Soybean yield bu/A	Weed control rating[a]		Soybean stand reduction %	Soybean yield bu/A
		Grasses			Broadleaves	Grasses		
2,4–D amine	1	7.0	38.3	12.9	6.7	5.7	9.5	29.7
2,4–D amine	2	9.7	78.3	7.1	9.0	6.7	31.0	25.7
Emid	2	9.0	45.0	10.7	8.0	6.0	34.0	26.5
Emid	4	10.0	65.0	9.7	9.3	8.0	62.5	14.2
4–(MCPB)	2	7.0	10.0	16.2	8.0	5.3	3.0	26.3
4–(MCPB)	4	9.0	51.7	14.8	9.0	7.3	31.0	27.0
NaPCP	12.5	2.3	0.0	13.4	7.7	6.3	0.0	31.3
NaPCP	25	8.3	0.0	20.6	8.7	7.7	0.0	31.3
PCP	12.5	2.0	0.0	18.1	6.7	6.0	0.0	27.9
PCP	25	7.5	0.0	19.8	8.0	7.3	3.5	29.3
DNBP	4	3.7	0.0	17.6	6.3	4.7	0.0	24.7
DNBP	8	6.7	0.0	22.4	9.0	7.7	2.0	26.3
NaNPA	2	6.7	15.0	14.8	6.7	6.3	1.0	29.8
NaNPA	4	9.0	18.3	13.0	7.7	7.0	0.0	27.9
BCPC	6	0.7	0.0	14.3	3.7	4.0	8.5	13.6
BCPC	12	5.7	0.0	14.0	5.3	7.7	10.0	16.1
CPPC	6	—	—	—	4.3	6.0	0.0	24.5
CPPC	12	—	—	—	6.0	8.0	2.0	23.3
CDAA	4	7.7	0.0	24.2	3.0	7.3	0.0	23.4
CDAA	8	9.7	0.0	26.9	3.7	8.7	0.0	22.4
CDEC	4	2.3	0.0	11.2	4.3	7.0	0.0	26.1
CDEC	8	6.7	6.7	10.2	6.0	8.3	1.5	29.0
Neburon	2	3.0	0.0	10.3	6.3	5.0	0.0	25.3
Neburon	4	7.3	0.0	15.9	8.3	7.7	0.5	29.9
3Y9	2	—	—	—	8.3	6.7	25.5	27.5
3Y9	4	—	—	—	8.7	8.0	50.0	21.7
NaPCP+Emid	10+2	9.0	28.3	16.0	9.3	6.3	34.0	27.5
NaPCP+Emid	20+4	10.0	71.7	8.1	10.0	8.3	63.5	8.1
NaPCP+CDEC	10+4	5.3	0.0	17.2	8.3	6.7	0.0	32.1
NaPCP+CDEC	20+8	8.3	0.0	25.7	9.3	8.0	12.0	30.2
Check[b]		0.0	0.0	16.4	0.0	0.0	0.0	20.7
Check-cultivated[c]		5.0	0.0	19.2	7.7	7.7	4.0	29.3
L.S.D. .05				10.1				9.7
.01				NS				12.0

[a]Weed control rating: 0 = no control, 10 = perfect control. Broadleaf population at Georgetown very sparse—crabgrass predominated.
[b]Check—received cultivation identical to chemically treated plots.
[c]Check-cultivated—received cultivation as needed, commencing at planting time.

yield. Fair weed control was obtained from 2,4,5–TES at 6 lbs. per acre but this treatment resulted in a serious reduction in soybean stand with a trend toward decreased yield of soybeans. The DNBP treatment resulted in poor control of weeds as well as reduced yield of soybeans.

1956. The results of the 1956 tests at Georgetown and Newark are presented in Table 3. Soil moisture at Georgetown at planting time, June 12, and the following 35 days was very favorable. Rainfall (inches) for this period was recorded as follows: June 14—.12, 15—.85, 17—.06, 18—.03, 21—.36, 22—.02, 25—.74, and 27—.16; July 4—.16, 5—.21, 6—.31, 8—1.03, 9—.44, 10—.14, 16—.11, and 17—.30. Maximum daily temperatures of 85° F or above for this same period were recorded for 24 days, 12 days of which were 90° F or above.

The sparse broadleaf population did not justify a weed control rating. The grass population was practically a pure stand of crab-

grass. CDAA at 8 lbs. per acre was superior to all other treatments included in this study (Table 3). Excellent weed control was obtained without any reduction in soybean yield. Even at the 4 lb. rate weed control was very satisfactory. In comparison, only fair control was achieved with CDEC at 8 lbs. per acre. In addition, the yield of soybeans was seriously reduced. NaPCP at 25 lbs. per acre and a mixture of NaPCP and CDEC at 20 and 8 lbs. per acre, respectively, very effectively controlled the grasses. The phenoxy compounds [2,4–D amine, Emid, and 4–(MCPB)] and NaNPA gave excellent control but on the other hand seriously reduced soybean yields.

Soil moisture at Newark at the time of planting, June 8, was ideal but above normal during the following 35 days. Rainfall (inches) was recorded as follows: June 11—.60, 16—1.02, 17—.46, 18—.20, 20—.22, 23—.90, and 27—.37; July 4—.18, 5—.26, 7—.12, 8—.81, and 9—1.32. Maximum daily temperatures of 85° F or above for the same period were recorded on 19 days, 11 days of which were 90° F or above.

The predominant weed population was pigweed and crabgrass. Again, the superiority of NaPCP alone or in mixtures was apparent (Table 3). Other treatments included in the study gave slightly better weed control but in all cases the trend was toward lower yields of soybeans. NaPCP at 25 lbs. per acre resulted in excellent broadleaf control and very good grass control. Although statistically not significant, the yield was 2.0 bu. per acre higher than the check-cultivated plot. In the control of grasses CDEC and CDAA each at 8 lbs. per acre performed very similarly. However, the CDEC treatment resulted in substantially better control of broadleaf weeds and higher soybean yield. The best control of all weeds resulted from the mixture of 20 lbs. of NaPCP and 8 lbs. of CDEC per acre.

Neburon, NaNPA, 4–(MCPB), and 3Y9 each at 4 lbs. per acre, DNBP at 8 lbs. per acre, and Emid at 2 lbs. per acre showed promise of satisfactory weed control. The tendency with all of these materials, excepting Neburon, was toward a slight reduction in soybean yield.

SUMMARY AND CONCLUSIONS

Herbicides were evaluated as pre-emergence treatments on soybeans at two locations in Delaware during the period 1954 to 56 inclusive. The soil type represented at the Georgetown location was a Norfolk loamy sand and at Newark a Sassafras loam. The results of these studies indicate the following:

1. Mixtures of NaPCP + CDEC and NaPCP + 2,4–D isopropyl ester have been the most effective treatments in the control of both broadleaves and grasses.

2. NaPCP at 25 lbs. per acre gave very good control of broadleaf weeds and fair control of grasses without any reduction in soybean yield. Recommendation of this herbicide for commercial application will be made if and when residue tolerances are established.

3. CDEC and CDAA each at 8 lbs. per acre have been very effective in the control of grasses. CDEC has been superior to CDAA at the Newark location but the reverse was true at the Georgetown location.

4. DNBP at 6 to 8 lbs. per acre was promising at both Georgetown and Newark.

5. NaNPA, Neburon, and 4–(MCPB) each at 4 lbs. per acre, Emid at 2 lbs. per acre, and 3Y9 at 2 lbs. per acre have given satisfactory weed control at both locations, but at Georgetown, particularly, have caused serious reduction in soybean yields.

LITERATURE CITED

1. ANONYMOUS. Suggested guide for chemical control of weeds. USDA, ARS Special Report. 1956.
2. BURT, E. O., ILLNICKI, R. D., and WILLARD, C. J. Pre-emergence herbicides on soybeans. Res. Rep. North. Central Weed Control Conf. p. 104–105. 1952.
3. CHAPPELL, W. E. Chemical vs. cultural control of weeds in soybeans. Proc. Northeastern Weed Control Conf. p. 301–306. 1954.
4. HARTWIG, E. E. Weed control, II—Mississippi Delta area. Soybean Digest 14 (6):18–19. 1954.
5. LEE, OLIVER C. Pre-emergence use of DNOSBP and CIPC in soybeans. Res. Rep. North Central Weed Control Conf. p. 104–105. 1952.
6. SLIFE, F. W. Controlling weeds in soybeans. Mimeo W-5, University of Illinois. 1955.
7. ———. Future of weed control in soybeans. Soybean Digest 16(5):12. 1956.
8. SMITH, R. J. Let us spray. Soybean Digest 15(6):8–9. 1955.
9. STANIFORTH, D. W., and WEBER, C. R. Effect of annual weeds on the growth and yield of soybeans. Agronomy Journal 48:467–471. 1956.
10. ———, and ———. Control of annual weeds in soybeans. Soybean Digest 16(5):10–11. 1956.
11. SYLVESTER, E. P. Weed control, I—In the North. Soybean Digest 14(6):14–17. 1954.
12. UPCHURCH, R. P. Field experiments conducted in North Carolina during 1953 and 1954 relating to weed control in soybeans. Proc. Southern Weed Control Conf. p. 162–170. 1955.
13. WILLARD, C. J. Ohio experiments on the chemical control of weeds. Soybean Digest 12(6):12–13. 1952.

BRIEF PAPERS

A Laboratory Test for Screening Chemicals for Toxicity to Submerged Aquatic Plants

M. S. HUDSON and BEE HUDSON[1]

IN 1955 studies were initiated to determine the toxicity of a large number of chemicals to submerged aquatic plants. It was hoped that those found most active would be useful for weed eradication from lakes and ponds. Procedures for screening chemicals for toxicity to aquatic plants are not well established. Chao[2] and Fromm (2) used a few leaves at a time of *Spirodela* and *Lemna* to determine plant sensitivity to several herbicides. Freeland (1) made short-time respiration studies on *Anacharis* with a similar objective. None of the procedures described were entirely suitable to use in a screening trial with entire plants. Therefore it was concluded that in order to carry out the toxicity screening tests it would first be necessary to develop a satisfactory method of culturing representative species in small vessels.

At the start of the work it was arbitrarily decided to use vessels of about 1 liter capacity, and so 1 quart fruit jars were chosen as the nearest size readily available. Plants used in the test were *Ceratophylum demersum* from Lake Kanuga, Hendersonville, N. C. and *Anacharis densa* from Zimmermans's Lake, Spartanburg, S. C. The plants were collected in December 1955. After a series of tests in solutions containing varying amounts of nutrients it was found the plants could be grown successfully in the solution shown in Table 1.

Table 1. Nutrients and concentrations used in preparing culture solutions.

Nutrient	Concentration in stock solution ppm	Concentration in culture solution ppm
Monocalcium phosphate	435	4.35
Sodium nitrate	270	2.70
Magnesium sulfate	740	7.40
Potassium chloride	210	2.10
Boric acid	0.25	0.0025
Iron citrate	0.5	0.0050
Manganese sulfate	0.5	0.0050
Copper sulfate	0.05	0.0005
Zinc sulfate	0.05	0.0005

The test specimens were prepared in the following manner. Approximately 100 grams of air dry white sand was placed in each jar and the jars filled with water from a tap. The jars were allowed to

[1]Consulting Chemist and Biological Assistant, Wofford College, Spartanburg, S. C.; respectively.

[2]Chao, Tung-Fang. A study of phytotoxic action of 2,4–dichlorophenoxyacetic acid on certain aquatic plants. Dissertation Publication 3644, University of Minnesota.

stand for about 10 seconds until the heavier particles had settled and the liquid containing the fine suspended matter was poured off. This was done four times. The purpose of this was to eliminate fine suspended matter so that the plants could be introduced without fear of their leaves becoming coated with silt. To the jars, which were found to hold 850 ml up to the ring at the lower end of the neck, were added 8.5 ml of the stock solution shown in Table 1. When the jars were filled with water the concentrations of the chemicals were one-hundredth of that of the stock solution. The jars were then allowed to stand for at least 48 hours for the chemicals to reach equilibrium by hydrolytic or other reactions.

Growing tips, or nodes taken from near the roots of healthy plants, were planted in the sand. The planted jars were kept at least 2 weeks and then were checked for active growth before being used in the chemical screening tests. The jars were kept on tables in a well-lighted laboratory but were not exposed to direct sunlight. Hours of light and darkness were those for average summer conditions. Temperatures ranged between 70 and 80° F.

In order to keep a check on the viability of the cultured plants sodium arsenite was used as the standard test chemical. At intervals during the screening tests several series of jars were poisoned with 1, 2, 3, 4, 5 and 6 ppm of sodium arsenite. In these tests it was found that the killing concentration was between 2 and 3 ppm for this chemical. The test jars from one of these sodium arsenite series is shown in Figure 1. No change in tolerance of the plants to this chemical was detected over a period of several months in culture.

Figure 1. Control of *Anacharis* with sodium arsenite. Jars from left to right: 2, 3 and 4 ppm of sodium arsenite and control.

A concentration of 1 ppm was used as the operating level for the screening tests. Because some of the chemicals had water solubilities of less than 1 part per 10,000 the operating level used with these materials was actually less than 1 ppm. In preparing the aqueous solutions of the chemicals 0.100 gm of the chemical were weighed out and transferred to a large beaker and 1000 ml of tap water was added. If the chemical did not dissolve immediately the solution was heated to 140–160° F with constant stirring. The solution was then allowed to stand until it cooled to room temperature. Enough of the solution was then filtered (usually about 100 ml) to give an adequate sample for the toxicity tests. Eight and one-half milliliters of this solution was then added to a jar containing one of the growing plants. This gave a concentration of 1 ppm of the chemical in the solution in contact with the plant provided all of the 0.100 gm of it remained in the liter of water after heating, cooling and filtering.

Nearly 200 chemicals were tested by this screening method and two were found which killed the plants at a concentration of 1 ppm or less. These were methyl rosaniline chloride and 1–chloro–2,4–dinitrobenzene.

LITERATURE CITED

1. FREELAND, R. O. Effects of 2,4–D and other growth substances on photosynthesis and respiration in *Anacharis*. Bot. Gaz. 111:319–324. 1950.
2. FROMM, F. Use of *Lemna minor* in rapid testing of toxicity to plants. Ciencia (Mexico) 7:214–218. 1946.

News and Notes

Johann Garimorth, who completed his graduate work at the Hochschule Fuer Boden Kultur at Vienna in 1956, will spend a year as a post-doctoral fellow at the Dept. of Horticulture at the University of Wisconsin. He will be engaged in research on weed competition in vegetable crops.

Dale Bush has joined the staff of the American Chemical Paint Co. as a technical advisor and will serve the middle west. Previously he was employed by the Nebraska State Dept. of Agriculture on its weed regulatory program.

Alden S. Crafts, Dept. of Botany, University of California at Davis, is taking a sabbatical leave of 1 year in England at the University of Oxford where he will observe weed control methods as they are practiced in Great Britain. In addition to this, he will continue his studies on the mechanism of action of herbicides in cooperation with G. E. Blackman and associates.

Jonas Vengris, Dept. of Agronomy, University of Massachusetts, will be visiting the Dept. of Agronomy, University of Wisconsin for 8 months on a sabbatical leave. He intends to become familiar with the weed control work in progress at a number of the north central states during this time.

The Third Annual Cornell Weed Day was held for all those interested in weed control on July 18, 1957. Tours were made to plots of agronomic and vegetable crops where weed control trials were shown. Informal programs the evening prior to the tour, and on the evening of July 18, were also arranged.

Notice of the availability of the Weed Control Handbook 1957 has been received. Copies may be obtained by writing to the British Weed Control Council, 86 Strand, London, W.C. 2. The price is 5s post free per copy and the check should be made out to British Weed Control Conference.

BIBLIOGRAPHY OF WEED INVESTIGATIONS
for
January, February, March, 1957

Table of Contents

	Reference Number
I. Economic Aspects and General Weed Problems	1
II. Botany of Weeds	
A. Classification and Identification	53
B. Ecological Investigations and Surveys	55
C. Physiological Investigations	61
D. Morphological and Anatomical Investigations	
E. Weed Seed Investigations	145
III. Weed Control	
A. Cultural	149
B. Chemical	
1. Weeds in field crops	151
2. Weeds in horticulture, ornamental and vegetable crops	216
3. Weeds in grasslands, including grass-legume pastures, rangeland, turf, lawns, and cemeteries	262
4. Weeds in specialized areas, including ditchbanks, canal ditches, fencerows, rights-of-way, irrigation ditches, and cities	282
5. Woody plants	285
6. Aquatic weeds	310
7. Specific weeds	313
C. Biological.	
IV. Chemical and Biochemical Investigations	
V. Special Characteristics of Weeds	
A. Poisonous Plants and Their Control	372
B. Uses of Weeds	
C. Pathological and Entomological Relationships	
VI. Nature and Properties of Chemicals Used as Herbicides	377
VII. Effect of Herbicides on Soils, Livestock, and Humans	409
VIII. Equipment, Methods of Application, and Herbicidal Calculations	416
IX. Legal Aspects	434

Prepared By
UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Crops Research Division

This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Crops Research Division, Agricultural Research Service, U.S.D.A. does not assume responsibility for the subject matter cited.

Beltsville, Maryland

I. Economic Aspects and General Weed Problems

1. Aberg, E. Chemical weed control. (In Swedish.) Lantbrtidskr. f. Dalarna 3:73–82. June 1956.
2. Allen, H. P. Weed problems in world agriculture. World Crops 8:217–222. June 1956.
3. Almond, F. L., and King, N. C. Weed control: herbicides or cultivation? So. African Sugar Technol. Assoc. Proc. 29:122–125. 1955.
4. Brauer, E. Fehler bei der unkrautbekämpfung. Mitschurin Bewegung 5:368. Apr. 15, 1956.
5. Eckstein, Z., Moszczynski, W., and Sobotka, W. From the problems of preparation of weed-killers. II. (In Polish.) Przem. Chem. 12:167–169. Ref. Mar. 1956.
6. Edmondson, V. W., and White, J. H. Costs of chemical and flame control of weeds in cotton. Ark. Agr. Expt. Sta. B. 569, 27 p. Apr. 1956.
7. Ferens, P. S. Results of aerial application in New Zealand. New Zeal. Weed Control Conf. Proc. 8:44–48. 1955.
8. Fisher, G. G., Allen, H. P., and Hunt, J. L. Weed and insect control. Agr. Merchant 36 (4):87–92. Apr. 1956.
9. Gilbert, C. J. Are we getting the job done in weed control? No. Cent. Weed Control Conf. Proc. 12:64–66. 1955.
10. Granstrom, B. The fight against weeds this year. (In Swedish.) Svensk Frötidn. 25:54–56. Apr. 15, 1956.
11. Hampson, C. P. Economics of weed control with special reference to MCPA. World Crops 8:223–226. Ref. June 1956.
12. Hemphill, D. D. Fruits. No. Cent. Weed Control Conf. Res. Rpt. 12:151–155. 1955.
13. Hubert, K. Weitere erfahrungen aus den jahren 1954 und 1955 bei der chemischen unkrautbekämpfung in Sachsen-Anhalt. Deut. Landwirt. 7:138–142. Ref. Mar. 1956.
14. Lacy, K. Let chemicals do the job—but be sure to show farmers *how*! Co. Agent & Vo-Ag Teacher 12(4):22–23. Apr. 1956.
15. Lacy, W. K. Here is a proven program to teach farmers weed control. Better Farming Methods 28(5):18. May 1956.
16. Lee, O. C. What is new in chemical weed control. Amer. Seed Trade Assoc. Hybrid Corn Div. Rpt. Hybrid Corn Indus. Res. Conf. 10:87–90. 1955.
17. Lee, O. C., and Warren, G. F. Recommended chemicals for weed control. Purdue U. Ind. Agr. Ext. Mimeo ID-1,11 p. Jan. 1955.
18. Little, E. C. S. The potentialities of helicopter spraying. New Zeal. Weed Control Conf. Proc. 8:49–57. 1955.
19. Longtin, E. J. Some biological, technical and administrative aspects of aquatic weed control in Minnesota. No. Cent. Weed Control Conf. Proc. 12:59–60. 1955.
20. Makarova, V. A. Bor'ba s sorniakami [Weed control]. Rostov-na-Donu, Rostovskoe Knizhnoe Izdatel'stvo, 1955.
21. McWhorter, C. G., Wooten, O. B., and Crowe, G. B. Economic value of chemical weed control. Miss. Farm Res. 19(3):1, 6. Mar. 1956.
22. McWhorter, C. G., Wooten, O. B., and Crowe, G. B. An economic evaluation of weed control practices in the Delta. Miss. Agr. Expt. Sta. C. 203, 7 p. Mar. 1956.
23. Netherlands. Plantenziektenkundige Dienst. Bericht over onkruidbestrijdingsmiddelen [Report on herbicides]. Netherlands. Plantenziektenk. Dienst. Ber. 1168, 8 p. Feb. 1956.
24. North Central Weed Control Conference. Proceedings, twelfth annual meeting, December 5–8, 1955, Omaha, Nebraska. n.p., 1955.
25. Northern Ireland. Ministry of Agriculture. The ragwort danger. North. Ireland. Min. Agr. Mon. Agr. Rpt. 31:43–45. June 1956.
26. Northern Ireland. Ministry of Agriculture. Weed menace. North. Ireland. Min. Agr. Mon. Agr. Rpt. 31:41–43. (Cont.) June 1956.
27. Nowinski, M. Das problem der unkräuter und ihre bekämpfung auf biologischer grundlage. (In Polish.) Poznańskie Towar. Przyjaciól Nauk. Wydz. Mat.-Przyrodniczy. Komis. Biol. Prace 18,146 p. 1955. German summary.
28. Nudel'man, Z. N. Herbicides. (In Russian.) Priroda 45(3):80–83. Ref. Mar. 1956. Weed control, chiefly.

29. OLSEN, H. K., and STAPEL, C. Oversigt vedrørende kemisk bekæmpelse af ukrudt, plantesygdomme og skadedyr i landbruget [Review of chemical control of weeds, plant diseases and pests in agriculture]. København, Landbrugets Informationskontor, 1955.
30. PEREZ, M. Combate de malas hierbas en Hawaii. Suelo Tico 8:141–144. Aug./Nov. 1955.
31. PETERSEN, H. I. Ukrudtsbekaempelse i U.S.A.; rapport over en studierejse til U.S.S. [Weed control in U.S.A.; report on a study trip to U.S.A.]. København, Udemrigsministeriet, 1965.
32. PRESTON, S. W. The Australian weed problem. New Zeal. Weed Control Conf. Proc. 8:123–129. 1955.
33. RADEMACHER, B. Entwicklungsstand in der unkrautkunde. Berlin. Biol. Bundesanst. f. Land- u. Forstwirt. Mitt. 85:171–186. Ref. Mar. 1956.
34. RAU, E. Unkrautbekämpfung in grünland. Gesunde Pflanzen 8:64–67. Apr. 1956.
35. ROBERTSON, R. D. Progress in the suppression of noxious weeds in Wanganui County. New Zeal. Weed Control Conf. Proc. 8:65–68. 1955.
36. SCHÜTZ, and LEHNERT, J. Chemische unkrautbekämpfung. Mitschurin Bewegung 5:408–414. May 1, 1956.
37. SCRAGG, E. B. Chemical methods of weed control. Scot. Agr. 35:190–195. Ref. Spring 1956,
38. SHAW, B. T. Weed control as a part of American agriculture. Washington, U. S. Agr. Res. Serv., 1956.
39. SHAW, W. C., and others. Suggested guide for chemical control of weeds. U. S. Agr. Res. Serv. ARS 22–23, 38 p. Apr. 1956.
40. SHEBESKI, L. H. What's new in weed control. Saskatchewan. U. Farm & Home Week. Addresses & Proc. 1956:31–33,35.
41. SMITH, N. J. How to kill 20 million weeds an hour! Amer. Veg. Grower 4(5):13,34. May 1956.
42. STAHLER, L. M. What is the future of weed control? No. Cent. Weed Control Conf. Proc. 12:73–74. 1955.
43. SYLWESTER, E. P. The farmer's chemical kit for weed control. No. Cent. Weed Control Conf. Proc. 12:67–70. 1955.
44. SYLWESTER, E. P. Here are your weed control chemicals. Hoard's Dairyman 101:528–529. May 25, 1956.
45. TREVETT, M. F., and CUNNINGHAM, C. E. A guide for the use of chemical weed killers in 1956. Maine Agr. Expt. Sta. Mimeo. Rpt. 59, 15 p. Jan. 1956.
46. VEATCH, C. Weed control—1956 suggestions. W. Va. Agr. Expt. Sta. Cur. Rpt. 13,11 p. Apr. 1956.
47. VIDME, T. Kjemisk ugrastyning i U.S.A.; melding om ei studiereis [Chemical weed thinning in U.S.A.; report on a study trip]. Oslo, Utvalget for Faglig Hjelp i Landbruket, 1955.
48. WALLACE, K. Teaching aids. No. Cent. Weed Control Conf. Proc. 12:16–17. 1955.
49. WASHINGTON. STATE COLLEGE. EXTENSION SERV. Weed killers. Wash. State Col. Ext. Ext. Mimeo. 1757, 26 p. Apr. 1956.
50. WELLHAUSEN, H. W. Guide for using chemicals in weed control. Ark. Agr. Col. Ext. Misc. P. 44, 8 p.-folder. 1956?
51. WILLARD, C. J., and ALBAN, E. K. Literature of chemical weed control. J. Agr. & Food Chem. 4:454–455. May 1956.
52. YOUNG, P. D. A short history of chemical weed control in Puerto Rico: what is a weed? Sugar J. 18(12):54–56. May 1956.

II. BOTANY OF WEEDS

A. Classification and Identification

53. BRAUN, R. Wie heisst das unkraut? Gesunde Pflanzen 8:68–69. Apr. 1956.
54. RAGONESE, A. E. Plantas tóxicas para el ganado en la región central Argentina. La Plata. U. Nac. Facul. de Agron. Rev. 31:133–336. Ref. Dec. 1955.

B. Ecological Investigations and Surveys

55. ASHBY, D. G., and PFEIFFER, R. K. Weeds, a limiting factor in tropical agriculture. World Crops 8:227–229. June 1956.

56. AZZI, G. Agricultural ecology. London, Constable, 1956.
57. BELOZEROV, P. I. In regard to the distribution of Elodea canadensis in the North [of U.S.S.R.]. (In Russian.) Bot. Zhur. [Moskva] 41:262–263. Ref. Feb. 1956.
58. GREEN, K. R. The problem of serrated tussock [Carex stricta] in New South Wales. Agr. Gaz. N. S. Wales 67:123–126,166. (Cont.) Mar. 1956.
59. JENKINS, B. C. Wildlife habitat development with herbicides in Michigan. No. Cent. Weed Control Conf. Proc. 12:58. 1955.
60. STANIFORTH, D. W. Plant competition studies with field corn and Setaria spp. No. Cent. Weed Control Conf. Proc. 12:3. 1955.

C. Physiological Investigations

61. AKERS, T. J., and FANG, S. C. Studies in plant metabolism. VI. Effect of 2,4–D on the metabolism of aspartic acid and glutamic acid in the bean plant. Plant Physiol. 31:34–37. Jan. 1956.
62. ALDERMAN, D. Alpha-naphthylacetamide: a chemical fruit thinner. Amer. Soc. Hort. Sci. Proc. 66:57–64. Dec. 1955.
63. ALSOPP, A. Apical dominance in Marsilea, with particular reference to the effects of 3-indolylacetic acid, 3-indolylacetonitrile, and coumarin on lateral bud development. J. Expt. Bot. 7(19):14–24. Ref. Feb. 1956.
64. ALSOPP, A. Morphogenetic effects of 3-indolylacetonitrile on sporelings of Marsilea in aseptic culture. J. Expt. Bot. 7(19):1–13. Ref. Feb. 1956.
65. ANDREAE, W. A., and VAN YSSELSTEIN, M. W. H. Studies on 3-indoleacetic acid metabolism. III. The uptake of 3-indoleacetic acid by pea epicotyls and its conversion oı 3-indoleacetylaspartic acid. Plant Physiol. 31:235–240. Ref. May 1956.
66. BAGLIONI, T. Action of some substances on the growth of roots of cucumber seeds (Cucumis sativus). (In Italian.) Soc. Ital. delle Sci. Vet. Atti 9:491–493. 1955, pub. 1956.
67. BALL, N. G., and DYKE, I. J. The effects of indole-3-acetic acid and 2:4–dichlorophenoxyacetic acid on the growth rate and endogenous rhythm of intact Avena coleoptiles. J. Expt. Bot. 7(19):25–41. Ref. Feb. 1956.
68. BALLARD, L. A. T. Flowering of skeleton weed [Chondrilla juncea]. Austral. Inst. Agr. Sci. J. 22:57–61. Mar. 1956.
69. BARAK, D. Spraying for thinning plums. (In Hebrew.) Hassadeh 36:547. Apr. 1956.
70. BARRIER, G. E., and LOOMIS, W. E. The translocation of herbicides. No. Cent. Weed Control Conf. Proc. 12:5. 1955.
71. BENEDICT, R. C. Auxin and Psilotum. Amer. Fern J. 46:30–31. Jan./Mar. 1956.
72. BEVILACQUA, L. R. Action of nicotinamide on the dehydrogenase of oat coleoptiles. (In Italian.) Accad. Ligure di Sci. e Let. Atti 11:115–118. 1954, pub. 1955.
73. BEVILACQUA, L. R. Action of nicotinamide on lengthening of oat coleoptiles. (In Italian.) Accad. Ligure di Sci. e Let. Atti 11:127–131. 1954, pub. 1955.
74. BOLLI, M. Respiration and osmotic pressure test on plants subjected to the action of ascorbic and indoleacetic acids. (In Italian.) Perugia. U. degli Studi. Facol. di Agr. Ann. 10:248–251. 1954.
75. BORSA, P. Sensitivity of wheat breeds to herbicides and anomalies observed. (In Italian) Milan. U. Facol. di Agr. Ann. (n.s.) 4:213–218. 1955.
76. BUSSE, M., and KANDLER, O. Uber die wirkungen der β-indolylessigsäure auf den stoffwechsel von avenakoleoptilen. Planta 46:619–642. Ref. 1956.
77. CALLAGHAN, J. J., and VAN NORMAN, R. W. Effect of foliar sprays of maleic hydrazide on photosynthesis. Science 123:894–895. May 18, 1956.
78. CHAVAROC, M. Contribution a l'étude de l'action du sel de soude de l'acide 2,4–dichlorophénoxyacétique sur les végétaux supérieurs. Rev. des Sci. Nat. d'Auvergne (n.s.) 20:49–77. Ref. 1954.
79. COOPER, W. C., PEYNADO, A., and OTEY, G. Effects of plant regulators on dormancy, cold hardiness, and leaf form of grapefruit trees. American Hort. Sci. Proc. 66:100–110. Ref. Dec. 1955.
80. CRAFTS, A. S. Use of labeled compounds in weed research. Internatl. Conf. Peaceful Uses Atomic Energy. Proc. 1955(12):157–158. Ref. 1956.

81. DASTUR, R. H., and BHATT, J. G. Study of the effect of chemical hormones on the carbohydrate and nitrogen contents of the cotton plant. Indian Cotton Growing Rev. 10:42–56. Ref. Jan. 1956.
82. DAVIDSON, F. F. Auxin-like properties of extracts from Phylloxera devastatrix Per. galls. Tex. J. Sci. 8:195–201. Ref. June 1956.
83. DEGMAN, E. S., and BATJER, L. P. Delayed effects of 2,4,5–trichlorophenoxypropionic acid sprays on Anjou pears. Amer. Soc. Hort. Sci. Proc. 66:84–86. Dec. 1955.
84. FERNQVIST, J. Thinning of fruit. (In Swedish.) Försök och Forsk. 13:53–55. Apr. 1956.
85. FERTIG, S. N., and VEGA, M. R. The inhibiting effect of maleic hydrazide (MH–40) on lawn grasses. Philippine Agr. 39:473–482. Ref. Jan. 1956.
86. FLETCHER, W. A. Facts about controlling pre-harvest drop of citrus. Orchardist New Zeal. 29(4):4–7. May 1956.
87. GAIMSTER, K. Plant-growth substances: ω-aryl- and ω-aryloxy-alkylcarboxylic acids. J. Sci. Food & Agr. 7:320–329. Ref. May 1956.
88. GARCIA GANCEDO, A. P. Algunas experiences realizadas con fitohormonas sobre diversas especies vegetales. Inst. Bot. A. J. Cavanilles. An. 13:79–94. 1954, pub. 1955.
89. GRIGSBY, B. H., and others. Growth of cucumbers, corn, field and snap beans following chemical sprays for control of quackgrass. No. Cent. Weed Control Conf. Proc. 12:46–47. 1955.
90. HALL, W. C. The effect of light and growth regulators on abscission and axillary bud growth in young cotton. Beltwide Cotton Defoliation Conf. Proc. 10:46–50. 1955.
91. HAMMAR, H. E. Effect of spray residues and other contaminants on leaf analysis. Plant Physiol. 31:256–257. May 1956.
92. HARRIS, R. W., and HANSEN, C. J. The effect of growth regulators on the drop of French prunes. Amer. Soc. Hort. Sci. Proc. 66:79–83. Dec. 1955.
93. HARRIS, R. W., and HANSEN, C. J. The effects of 2,4,5–trichlorophenoxyacetic acid on the development and maturation of the French prune. Amer. Soc. Hort. Sci. Proc. 66:73–78. Dec. 1955.
94. HARRIS, R. W., and HANSEN, C. J. Prune size affected by 2,4,5–T; erratic response in fruit size obtained after experimental treatment of mature trees with sprays of growth regulator. Calif. Agr. 10(4):6,15. Apr. 1956.
95. HAY, J. R. The effect of 2,4–dichlorophenoxyacetic acid and 2,3,5–triiodobenzoic acid on the transport of indoleacetic acid. Plant Physiol. 31:118–120. Mar. 1956.
96. HAY, J. R. The effect of 2,4–D and TIBA on an auxin transport mechanism in bean stems. No. Cent. Weed Control Conf. Proc. 12:4–5. 1955.
97. HAY, J. R. Translocation of herbicides in marabu [Caillica glomerata]. I. Translocation of 2,4,5–trichlorophenoxyacetic acid following application to the bark or to cut-surfaces of stumps. Weeds 4:218–226. Ref. July 1956.
98. HEATH, O. V. S., and CLARK, J. E. Chelating agents as plant growth substances; a possible clue to the mode of action of auxin. Nature [London] 177:1118–1121. June 16, 1956.
99. HERICH, R. Einwirkung der 2,4–dichlorphenoxyessigsäure auf die differenzierung des geschlechtes des hanfs (Cannabis sativa L.). (In Czech.) Biológia [Bratislava] 10:760–764. Ref. 1955.
100. HIELD, H. Z., RIEHL, L. A., and DEWOLFE, T. A. Isopropyl 2,4–D again available as growth regulator. Calif. Citrog. 41:260–262. May 1956.
101. HIELD, H. Z., RIEHL, L. A., and DEWOLFE, T. A. Isopropyl 2,4–D again available as growth regulator for citrus. Citrus Leaves 36(5):10–11. May 1956.
102. HOSKIN, F. C. G. The basic esters of some plant growth regulators. Amer. Chem. Soc. J. 78:3121–3122. July 5, 1956.
103. HOUSLEY, S., and BENTLEY, J. A. Studies in plant growth hormones. IV. Chromatography of hormones and hormone precursors in cabbage. J. Expt. Bot. 7:219–251. Ref. May 1956.
104. HOWELL, M. J. Physiological studies of the sweetpotato (Ipomoea batatas). Phase I: Effects of chemical treatments on sprout production. Phase II: Chemical induction of flowering. Diss. Abs. 16:1034–1035. June 1956.

105. HOWELL, M. J., and WITTWER, S. H. Further studies on the effects of 2,4-D on flowering in the sweetpotato. Amer. Soc. Hort. Sci. Proc. 66:279–283. Ref. Dec. 1955.
106. ISOGAI, Y. Studies on the growth promoting agents separated from etiolated bean seedlings. I. Tokyo. U. Col. Gen. Educ. Sci. Papers 5:139–147. Dec. 1955.
107. JAWORSKI, E. G. Tracer studies with 1-C^{14}- pentachlorophenol in cotton. Beltwide Cotton Defoliation Conf. Proc. 10:36–40. 1955.
108. KELLEY, V. W. Effect of certain thinning materials on number of fruit buds formed in Elberta and Halehaven peaches. Amer. Soc. Hort Sci. Proc. 66:67–69. Dec. 1955.
109. KELLEY, V. W. Effect of naphthaleneacetic acid on the transpiration of Jonathan apple shoots. Amer. Soc. Hort Sci. Proc. 66:65–66. Dec. 1955.
110. KELLEY, V. W. Time of application of naphthaleneacetic acid for fruit thinning of the peach in relation to the June drop. Amer. Soc. Hort. Sci. Proc. 66:70–72. Dec. 1955.
111. KENNARD, W. C. Effect of defoliation on two clones of Derris elliptica. Trop. Agr. [St. Augustine] 33:158–161. Apr. 1956.
112. KLEIN, R. M., and VOGEL, H. H. Necessity of indoleacetic acid for the duplication of crown-gall tumor cells. Plant Physiol. 31:17–22. Ref. Jan. 1956.
113. LAKSHMIKANTHAM, M., and PRASADARAO, K. K. Preliminary studies on the effect of spraying 2,4-D on juice quality of sugarcane. Sugar Technol. Assoc. India. Proc. 23:109–118. Ref. 1954.
114. LAL, G. Effect of spraying dilute solutions of 2.4.D on growing cane. Indian Sugar [Calcutta] 6:77–78. Apr. 1956.
115. LONGHURST, W. M. Stump sprouting of oaks in response to seasonal cutting. J. Range Mangt. 9:194–196. July 1956.
116. LOOMIS, W. E. Basic studies. No. Cent. Weed Control Conf. Res. Rpt. 12:179–186. 1955.
117. LUCKWILL, L. C. Two methods for the bioassay of auxins in the presence of growth inhibitors. J. Hort. Sci. 31:89–98. Ref. Apr. 1956.
118. MASERA, M. Research on plant hormone type products used for brush control in mountain areas. I. (In Italian.) Milan. U. Facol. di Agr. Ann. (n.s.) 4:253–262. 1955.
119. MCCORQUODALE, D. J. Prevention of the inhibitory effects of imidazole, benzimidazole, and histamine on mitosis and root elongation in Vicia faba roots. Diss. Abs. 16:220. Feb. 1956.
120. MECCA, S. B. Growth substances. Dahlia 25:8, 27–29. Spring 1956.
121. MOISEEVA, M. N. Phytohormones in the life of plants. (In Ukrainian.) Bot. Zhur. [Kyiv] 12:83–100. Ref. 1955.
122. NELSON, R. T. Effect of chemical treatment on respiration of sugar beets. Amer. Soc. Sugar Beet Technol. J. 9:21–24. Apr. 1956.
123. NITSCH, J. P., and NITSCH, C. Studies on the growth of coleoptile and first internode sections. A new, sensitive, straight-growth test for auxins. Plant Physiol. 31:94–111. Ref. Mar. 1956.
124. NORMAND, W. C. Studies of some effects of herbicides on cotton. Diss. Abs. 15:1989. Nov. 1955.
125. NYBOM, N. On the differential action of mutagenic agents. Hereditas 42:211–217. Ref. 1956.
126. PETRI, P. S. The use of bile as rooting substance. (In Italian.) Nuovo Gior. Bot. Ital. (n.s.) 61:736–740. 1954.
127. POWELL, L. E. A study of some non-acidic growth substances in apple leaves. Diss. Abs. 16:228–229. Feb. 1956.
128. QUINTIN, S. Considérations évolutives a la suite de modifications histologiques provoquées chez les tiges d'Araucaria excelsa par l'acide indol-β-acétique et l'acide 2-4-dichlorophénoxyacétique. Toulouse. Soc. d'Hist. Nat. B. 90:441–457. Ref. Third/Fourth Q. 1955.
129. RAI, G. S., and HAMNER, C. L. Respiratory activity of certain plant species as affected by sodium trichloroacetate (TCA). Mich. Agr. Expt. Sta. Q. B. 38:555–558. Ref. May 1956.
130. REINHOLD, L., and POWELL, R. G. A stimulatory action of indole-3-acetic acid on the uptake of amino-acids by plant cells. Nature [London] 177: 658–659. Apr. 7, 1956.

131. ROGERS, B. J. The distribution of radioactive amino triazole in plants. No. Cent. Weed Control Conf. Proc. 12:3–4. 1955.
132. ROHRBAUGH, L. M., and RICE, E. L. Relation of phosphorus nutrition to the translocation of 2,4–dichlorophenoxyacetic acid in tomato plants. Plant Physiol. 31:196–199. Ref. May 1956.
133. SAND, P. F., and SHAFER, N. E. The effect of isooctyl ester of 2,4–D on eight varieties of oats. No. Cent. Weed Control Conf. Proc. 12:24–25. 1955.
134. SCHIEFERSTEIN, R. H., and LOOMIS, W. E. The surface wax of leaves. No. Cent. Weed Control Conf. Proc. 12:2. 1955.
135. SCHIEFERSTEIN, R. H., and LOOMIS, W. E. Wax despoits on leaf surfaces. Plant Physiol. 31:240–247. Ref. May 1956.
136. SCHOLZ, E. W., LOOMIS, W. E., and LANTZ, H. L. Effect of 2,4–D on Concord grape. No. Cent Weed Control Conf. Proc. 12:57. 1955.
137. SISLER, E. C., DUGGER, W. M., and GAUCH, H. G. The role of boron in the translocation of organic compounds in plants. Plant Physiol. 31:11–17. Ref. Jan. 1956.
138. TAGUCHI, K., and NISHIIRI, K. Seed-setting in potatoes as affected by treatment of 2,4–D (2,4–dichlorophenoxyacetic acid.) (In Japanese.) Tohoku Natl. Agr. Expt. Sta. Rpt. 4:27–33. Feb. 1955.
139. TAKEDA, A., and SENDA, J. Induction of parthenocarpy with N-arylglycines. (In Japanese.) Nōgaku Kenkyū 43:178–180. Mar. 1956.
140. VAN OVERBEEK, J. Absorption and translocation of plant regulators. Annu. Rev. Plant Physiol. 7:355–372. Ref. 1956.
141. VLITOS, A. J., MEUDT, W., and BEIMLER, R. The role of auxin in plant flowering. IV. A new unidentified naturally occurring indole hormone in normal and gamma irradiated Maryland mammoth tobacco. Boyce Thompson Inst. Contrib. 18:283–293. Apr./June 1956.
142. WEI, A. F. The problem on the use of plant growth stimulating substances to prevent pre-harvest drop of apples. (In Chinese.) Acta Agr. Sinica 6:285–292. Ref. Aug. 1955.
143. WILLIAMS, M. C., SLIFE, F. W., and HANSON, J. B. Absorption and translocation of radio-active 2,4–D in certain weed species. No. Cent. Weed Control Conf. Proc. 12:10–11. 1955.
144. YASUDA, G. K., PAYNE, M. G., and FULTS, J. L. The effect of 2,4–D and maleic hydrazide on potato proteins as measured by paper electrophoresis. Colo.-Wyo. Acad. Sci. J. 4(7):52. Dec. 1955.

D. Morphological and Anatomical Investigations

E. Weed Seed Investigations

145. KÁS, V. Transfer of weeds by stable manure. (In Czech.) Za Socialist. Zeměděl. 6:204–208. Feb. 1956.
146. LEGGATT, C. W. Classification of weed seeds. *In* Organisation for European Economic Co-operation. European Productivity Agency. Testing of agricultural seeds moving in international trade, p. 59–60. Paris, 1955.
147. ROGERS, B. J., and STEARNS, F. W. Preliminary studies on the germination of weed seeds. No. Cent Weed Control Conf. Proc. 12:7. 1955.
148. STEARNS, F. The influence of light and temperature on germination and flowering of five species of Plantago. No. Cent. Weed Control Conf. Proc. 12:8. 1955.

III. Weed Control

A. Cultural

149. CHERNENKOV, A. D. Complex mechanization of sugar beet culture under conditions of a humid climate. (In Russian.) Zemledelie 4(3):79–81. Mar. 1956.
150. LARSON, R. E. Mechanical considerations. No. Cent. Weed Control Conf. Res. Rpt. 12:178. 1955.

B. Chemical

1. *Weeds in field crops*

151. ALLEY, H. P., and BOHMONT, D. W. Dalapon for control of weeds in sugar beets. Down Earth 11(4): 10–11. Spring 1956.

152. ANDERSON, L. E. Sorghum. No. Cent. Weed Control Conf. Res. Rpt. 12:91–93. 1955.
153. ANDERSON, L. E. Winter wheat. No. Cent. Weed Control Conf. Res. Rpt. 12:90. 1955.
154. ANDERSEN, R. N. Sugar beets. No. Cent. Weed Control Conf. Res. Rpt. 12:125–128. 1955.
155. ARAI, M., and MIYAHARA, M. Studies on weed control by submergence in rice cultivation. I–II. (In Japanese.) Crop. Sci. Soc. Japan. Proc. 24-163–165. Apr. 1956.
156. BAKKE, A. L. Herbicides for flax. Flax Inst. U. S. [Papers & Proc.], Nov. 17/18, 1955:24–26.
157. BENAVIDES GOMEZ, M. Control práctico de las malezas en los cultivos del frijol, en el Valle del Cauca. Agr. Trop. 12:221–227. Apr. 1956.
158. BERRETT, M. R. Do you have a grass problem? Sugar Beet J. 21(8):3. May 1956.
159. BONDAREV, A. A. Weed eradication in corn plantings with 2,4–D herbicide. (In Russian.) Zemledelie 4(3):107–108. Mar. 1956.
160. BOSE, A. K. Some observations with 2,4–D as a weed killer. Bihar Acad. Agr. Sci. Proc. 4:147–149. 1955.
161. BREAKEY, W. J. Spring sown grain. No. Cent. Weed Control Conf. Res. Rpt. 12:83,85–89. 1955.
162. BROWN, L. C., and HYER, A. H. Some effects of amino triazole and maleic hydrazide on second growth and defoliation of cotton. Beltwide Cotton Defoliation Conf. Proc. 9:58. 1955.
163. BUCHHOLTZ, K. P., and PETERSON, D. R. Weed control in field crops. Wis. Agr. Col. Ext. C. 447, rev., 12 p. May 1956.
164. BYLTERUD, A. Control of weeds in potato fields. (In Norwegian.) Norsk Landbr. 22:255–256. May 25, 1956.
165. CALLAND, J. W. Soybean growers tell how they control weeds. Soybean Digest 16(7):8–9. May 1956.
166. COITEUX, F. Les herbicides et le controle des mauvaises herbes dans nos cultures de betterave a sucre. Quebec Soc. Ptotect. Plants. Rpt. 36:70–73. May 1956.
167. DADASHEVA, SH. G. Data on the study of weeds of cereals in Nakhichevan ASSR. (In Russian.) Akad. Nauk Azerbaĭdzhansk. SSR. Inst. Zeml. Trudy 3:113–125. 1955.
168. DOOTJES, E. Control of weeds on arable land. (In Dutch.) Netherlands. Rlandbconsschap. v. Noordelijk Zuid-Holland. Verslagen en Meded. 2:73–80. 1955.
169. DUNHAM, R. S. Control of weeds in flax. Flax Inst. U. S. [Papers & Proc.], Nov. 17/18, 1955:36–37.
170. ENNIS, W. B. Chemical controls aid cotton farmers. Cotton Trade J. Internatl. Ybk. 23:34–35, 40–41, 46–47. 1955/56.
171. FLAME weeding for cotton; a full official report. Butane-Propane News 18(6): 42–43, 47, 49. June 1956.
172. FRIESEN, H. A. MCP vs. 2,4–D for the control of weeds in grain crops. No. Cent. Weed Control Conf. Proc. 12:23–24. 1955.
173. GLEASON, L. S., NIETO, J., and RAMIREZ, J. Pre-emergence weed control in potatoes in Mexico's high mountain valleys. No. Cent. Weed Control Conf. Proc. 12:47–48. 1955.
174. GRANSTROM, B. Difficult weeds in spring planted crops. (In Swedish.) Försök och Forsk. 13:73–74. June 1956.
175. GUZMAN, V. L. Grass control in sugar cane grown in organic soils. Fla. Everglades Expt. Sta. Mimeo Rpt. 56–14, 10 p. May 21, 1956.
176. HOPNER, E. Zur frühjahrs-unkrautbekämpfung im wintergetreide. Betriebswirt. Mitt. f. den Wirtberater. 22:13–14. Mar. 15, 1956.
177. IWASAKI, K., TOMABECHI, Y., and OGATA, H. Weed control by the weeders before germinating of crop plants. (In Japanese.) Tokohu Natl. Agr. Expt. Sta. Rpt. 5:167–171. Mar. 1955.
178. KASAHARA, Y., and others. Studies on the control of weeds on the field of winter cereals after rice crop. III. (In Japanese.) Nōgaku Kenkyū 43:181–212. Ref. Mar. 1956.

179. LACROIX, L., and DETROUX, L. Au sujet du désherbage chimique des cultures de mais. II. Essais de l'année 1955. Rev. de l'Agr. 9:381–398. Apr. 1956.
180. LIFSHITZ, N. Control of weeds in cotton. (In Hebrew.) Hassadeh 36:522–523. Apr. 1956.
181. MAKODZEBA, I. A., and PODOPRIGORA, V. S. A promising preparation for the control of cereal weeds. (In Russian.) Zemledelie 4(5):119–120. May 1956.
182. MCWHORTER, C. G. Controlling weeds will save money at gins, oil mills. Cotton Gin & Oil Mill Press 57(9):54–55. May 5, 1956.
183. MUKERJI, S. K., and CHATTERJI, B. N. Preliminary observations on some rabi weeds at Sabour under different cropping. Bihar Acad. Agr. Sci. Proc. 4:110–112. 1955.
184. NETHERLANDS. PLANTENZIEKTENKUNDIGE DIENST. Onkruidbestrijding met DNC in granen [Control of weeds in grain with DNC]. Netherlands. Plantenziektenk. Dienst Ber. 1172,3p. Mar. 1956.
185. OTTEN, R. J. Weed control in corn. Rur. New Yorker 106:378. May 19, 1956.
186. PARKER, C. Chemical control of weeds in sugar beet. Brit. Sugar Beet Rev. 24:161–164. June 1956.
187. PASTOR BOGGIANO, M., and PASTOR BOGGIANO, G. Un nuevo herbicida [CMU] para el control de las malas hierbas en el cultivo de la caña de azúcar. Conv. de Tecnol. Azucareros. An. 4:65–70. 1955.
188. PHILLIPS, W. M. Chemical drying and pre-harvest weed control. No. Cent. Weed Control Conf. Res. Rpt. 12:170–172. 1955.
189. POIGNANT, P. Les emplois en agriculture des désherbants sélectifs et des régulateurs de végétation; le désherbage des céréales. Agriculture [Paris] 19:79, 81–83, 85–86. Mar. 1956.
190. PORTER, W. K., and others. Chemical weed control in cotton. La. Agr. Expt. Sta. C. 42,8 p. Feb. 1956.
191. RASMUSSEN, L. W., and WOLFE, H. H. Weed control in cereal crops. Wash. State Col. Ext. Ext. Misc. P. 1, rev., 6 p.-folder. Mar. 1956.
192. RICCI, A. Herbicides: what they are and how they are used; weed control in grain. (In Italian.) Romagna Agr. e Zootec. 41:141–146. Apr. 1956.
193. ROBINSON, R. G. Flax. No. Cent. Weed Control Conf. Res. Rpt. 12:104–110. 1955.
194. ROCHECOUSTE, E. Weed control. Mauritius Sugar Indus. Res. Inst. Annu. Rpt. 1955:59–67.
195. RODGERS, E. G., BURT, E. O., and MIXON, A. C. Chemical weed control in peanut fields. Fla. U. Agr. Ext. C. 146, 8 p. Jan. 1956.
196. SAND, P. F. Forage legumes. No. Cent. Weed Control Conf. Res. Rpt. 12:116–122. 1955.
197. SCHUTZ, W. Jetzt das unkraut in den wintersaaten bekämpfen! Mitschurin Bewegung 5:320–321. Apr. 1, 1956.
198. SEXSMITH, J. J. Field and canning peas. No. Cent. Weed Control Conf. Res. Rpt. 12:134–136. 1955.
199. SHEBESKI, L. H. The effect of wild mustard removal by MCP or 2,4–D at various stages of growth of wheat, oats or barley. No. Cent. Weed Control Conf. Proc. 12:25–26. 1955.
200. SLIFE, F. W. Soybeans. No. Cent. Weed Control Conf. Res. Rpt. 12:111–115. 1955.
201. SLIFE, F. W. Laboratory and field studies with several A-chloroacetamides and chlorallyl dithiocarbamates on corn and soybeans. No. Cent. Weed Control Conf. Proc. 12:26–27. 1955.
202. SMITH, R. J. Controlling weeds in rice. Rice J. 59(5):51. May 1956.
203. SMITH, R. J. Controlling weeds in rice. Ark. Farm Res. 5:2. Spring 1956.
204. STANIFORTH, D. W. Control of certain annual grass weeds in corn. No. Cent. Weed Control Conf. Proc. 12:27–28. 1955.
205. STANIFORTH, D. W., Corn. No. Cent. Weed Control Conf. Res. Rpt. 12:94–103. 1955.
206. STEFFEN, G. Gesundes kartoffelsaatgut durch entfernung des krautes. Landtechnic 11:218–220. Apr. 30, 1956.

207. STEWART, M. J. A survey of chemical weed control in sugarcane. So. African Sugar Technol. Assoc. Proc. 29:126–135. Ref. 1955.
208. SWAN, D. G., CHILCOTE, D. O., and FURTICK, W. R. Chemical weed control in wheat, barley, oats. Oreg. Agr. Expt. Sta. C. Inform. 557, 8 p.–folder. Apr. 1956.
209. TIMM, E. Unkrautbesatz im brotgetreide bei der letzten inlandernte. *In* Arbeitsgemeinschaft Getreideforschung. Die qualitätszüchtung von brotgetreide, p. 85–88. Detmold, 1955.
210. WALLACE, K., and DERSCHEID, L. A. Chemical weed control in crops. S. Dak. State Col. Agr. Ext. Ext. L. 177, 6 p.-folder. June 1956.
211. WIESE, A. F., and REA, H. E. Chemical control of broadleaved annuals in sorghums. Tex. Agr. Expt. Sta. Prog. Rpt. 1861, 3 p. Apr. 4, 1956.
212. WIESE, A. F., and REA, H. E. Use of 2,4–D on winter wheat. Tex. Agr. Expt. Sta. Prog. Rpt. 1860, 2 p. Apr. 4, 1956.
213. WILLIAMS, R. E. Weeds in rice. VI–VII. Rice J. 59(5):24; (6):34–35. May–June 1956.
214. WILLIAMSON, E. B. Successful weed control. Cotton Trade J. Internatl. Ybk. 23:58,61. 1955/56.
215. WOOD, H. E. An appraisal of chemical weed control in field crops. No. Cent. Weed Control Conf. Proc. 12:29–30. 1955.

2. *Weeds in horticulture, ornamental and vegetable crops*

216. ALBAN, E. K. Chemicals used in weed control studies with potatoes. Ohio Veg. & Potato Growers Assoc. Annu. Proc. 41:110–115. 1956.
217. ALBAN, E. K. Vegetable "root crops." No. Cent. Weed Control Conf. Res. Rpt. 12:137–145. 1955.
218. BARRONS, K. C. Weed and grass control in fruit plantings. Oreg. State Hort. Soc. Proc. 47:83–84. 1955.
219. BURGIS, D. S. Oktone for pre-emergence chemical weed control in crucifers. Fla. State Hort Soc. Proc. 68:206–208. 1955.
220. CARLSON, R. F. CMU as a herbicide in vineyards. Mich. Agr. Expt. Sta. Q. B. 38:409–412. Feb. 1956.
221. CARLSON, R. F. The effect of CIPC on field sorrel in strawberry plantings. Mich. Agr. Expt. Sta. Q. B. 38:365–367. Feb. 1956.
222. CHADWICK, L. C., BARKER, P. A., and CHAMBERS, W. D. Chemical weed control in a Taxus nursery. No. Cent. Weed Control Conf. Proc. 12:52. 1955.
223. CHADWICK, L. C., and BARKER, P. A. Tolerances of certain nursery stock to CMU and SES. No. Cent. Weed Control Conf. Proc. 12:52. 1955.
224. CHADWICK, L. C., and Chambers, W. D. Chemical growth suppression of nursery companion crops. No. Cent. Weed Control Conf. Proc. 12:51. 1955.
225. CHADWICK, L. C., and CHAMBERS, W. D. Elimination of vegetation with TCA and Dalapon. No. Cent. Weed Control Conf. Proc. 12:57. 1955.
226. CONNOLD, W. Q. Sulphuric acid for the control of weeds in kale. Gt. Brit. Min. Agr. Fisheries & Food. Agriculture 63:21–22. Apr. 1956.
227. DANA, M. N. Weed control in Wisconsin cranberry marshes. No. Cent. Weed Control Conf. Proc. 12:50. 1955.
228. DANIELSON, L. L. Chemical control of weeds in vegetable crops. Veg. Growers Assoc. Amer. Annu. Rpt. 1955:151–154.
229. ETENEAU, J., and PRALORAN, J. C. L'effet de pulvérisation d'acide 2-4D sur la chute hivernale des pomelos "Marsh Seedless." Fruits et Primeurs de l'Afrique du Nord 26(275):29–39. Jan./Feb. 1956.
230. FURTICK, W. R., and CHILCOTE, D. O. Chemical weed control in mint. Oreg. Agr. Expt. Sta. C. Inform. 559, 6 p.-folder. Mar. 1956.
231. GUZMAN, V. L., and WOLF, E. A. Weed control in peppers grown on organic soils. Fla. State Hort. Soc. Proc. 68:202–205. 1955.
232. GUZMAN, V. L., and WOLF, E. A. Pre-emergence weeding with three rates of CIPC in combination with post-emergence weeding with pelletized CIPC in three varieties of onions. Amer. Soc. Hort. Sci. Proc. 66:284–288. Dec. 1955.
233. HANSON, N. S. How herbicides act on weeds. Sugar 51(4):46,48. Apr. 1956.

234. HEMPHILL, D. D. Weed control around newly transplanted apple trees. No. Cent. Weed Control Conf. Proc. 12:49. 1955.
235. HEMPHILL, D. D. Good-bye, weeds. Amer. Fruit Grower. West. Ed. 76(4): 42–45. Apr. 1956.
236. HERRON, J. W., and CHAPLIN, C. E. Weed control in strawberries. No. Cent. Weed Control Conf. Proc. 12:49–50. 1955.
237. HOLM, L. G., and TAYLORSON, R. Mixtures of herbicides for nursery weed control. No. Cent. Weed Control Conf. Proc. 12:51–52. 1955.
238. JAARSVELD, T. G. VAN, and STAALDUINE, D. VAN. Control of weeds in leek cultures. (In Dutch.) Groenten en Fruit 11:1063. Mar. 29, 1956.
239. KRUGER. Application "'Bulpur" on onions, 1954 Höfchen-Briefe 8:110–112. 1955.
240. LANING, E. R. Chemical weed control in vegetable crops—1955. Oreg. State Hort. Soc. Proc. 47:129. 1955.
241. LEVONEN, H. J., and MUKULA, J. On weed control with petrol products in the growing of umbelliferous plants. (In Finnish.) Finland. Maatalouden Koetoiminnan Keskusvaliokunta. Maatalous ja Koctoiminta 10:97–103. 1956.
242. LIFSHITZ, N. Control of weeds in onion areas. (In Hebrew.) Hassadeh 36:331–332. Feb. 1956.
243. MOORE, J. F. The efficiency of weed control with certain herbicides, and their effect on growth and yield of cannery spinach. Amer. Soc. Hort. Sci. Proc. 66:293–297. Dec. 1955.
244. PEABODY, D. V., and WOLFE, H. H. Weed control in green peas for western Washington. Wash. State Col. Ext. Ext. Misc. P. 15, rev., 3p. Apr. 1956.
245. PELTIER, G. L. Dalapon. Cranberries 20(12):12–13. Apr. 1956.
246. PEREZ-SALAS Y LAMO DE ESPINOSA, J. Empleo de herbicidas en primavera. Rev. Vinic. y de Agr. (ser.2)115:11. May 1956.
247. RIES, S. K. New weed control developments in processing crops. Canning Trade 78(41):8. Apr. 30, 1956.
248. RIES, S. K., and GRIGSBY, B. H. The post-emergence application of herbicides to tomatoes at different times and locations. No. Cent. Weed Control Conf. Proc. 12:55–56. 1955.
249. SAKO, J. The use of chlorates in destroying perennial weeds in apple orchards. (In Finnish.) Finland. Maatalouden Koetoiminnan Keskusvaliokunta. Maatalous ja Koetoiminta 10:80–84. 1956.
250. SEMIKHNENKO, P. G. Preplanting soil preparation for sunflower. (In Russian.) Zemledelie 4(4):83–87. Apr. 1956.
251. SINGLETARY, C. C., and HERRON, J. W. Pre-emergence herbicide treatments on lima beans, snap beans and sweet corn. No. Cent. Weed Control Conf. Proc. 12:45–46. 1955.
252. SOLOV'EVA, N. V., and ALIEV, A. G. Dodder control in vineyards. (In Russian.) Sad i Ogorod 5:69–70. May 1956.
253. TILL, J. F. The control of weeds in Brassica crops. New Zeal. Weed Control Conf. Proc. 8:74–76. 1955.
254. WARDEN, R. L., and DAVIDSON, J. H. Performance of Erbon for extended vegetation control in the North Central States. No. Cent. Weed Control Conf. Proc. 12:62–63. 1955.
255. WARREN, G. F. Some new possibilities for weed control in carrots. No. Cent. Weed Control Conf. Proc. 12:47. 1955.
256. WARREN, G. F. Other vegetables. No. Cent. Weed Control Conf. Res. Rpt. 12:146–150. 1955.
257. WARREN, G. F. Weed control in transplanted tomatoes. No. Cent. Weed Control Conf. Proc. 12:55. 1955.
258. WEAVER, R. J. Plant regulators in grape production. Calif. Agr. Expt. Sta. B. 752,26 p. Jan. 1956.
259. WEED control; a panel. Oreg. State Hort Soc. Proc. 47:63–65. 1955.
260. WESTROP, A. R. Some preliminary notes on weed-killing in tea with sodium chlorate. Nyasaland Farmer & Forester 3(2):29–31. May 1956.
261. WOLF, E. A., and GUZMAN, V. L. Combination of chemical and mechanical weed control in three varieties of onions in muck soil. Amer. Soc. Hort. Sci. Proc. 66:289–292. Dec. 1955.

3. *Weeds in grasslands (pastures, etc.)*

262. ALLEN, H. P. Weed control in grasslands in United Kingdom. New Zeal. Weed Control Conf. Proc. 8:130–141. Ref. 1955.
263. BELL, J. E. Weed problems of the Waikato. New Zeal. Weed Control Conf. Proc. 8:7–12. 1955.
264. BYLTERUD, A. No space for buttercups in meadows and pastures. (In Norwegian.) Norsk Landbr. 22:176–178. Apr. 13, 1956.
265. CALDART, F. Weeds infesting permanent meadows and pastures. (In Italian.) Monti e Boschi 7:175–180. Apr. 1956.
266. CENTRE NATIONAL DE RECHERCHES HERBAGÈRES ET FOURRAGÈRES (BELGIUM). Verslag. Onkruidonderzoek en verbetering van de graslandflora [Report: Weed research and improvement of grassland flora], 6th. Gent. 1955. 18 p.
267. ELLIOTT, I. L. Pasture management and weed control. New Zeal. Weed Control Conf. Proc. 8:40–43. 1955.
268. ELWELL, H. M. Control of brush on rangeland and pastures. No. Cent. Weed Control Conf. Res. Rpt. 12:160–162. 1955.
269. GARMHAUSEN, W. J. Turf management on Ohio's roadsides. Natl. Agr. Chem. Assoc. News & Pesticide Rev. 14(4):10–11. Mar./Apr. 1956.
270. GREEN, K. R. The problem of serrated tussock in New South Wales. Agr. Gaz. N. S. Wales 67:8–14, 41. (Cont.) Jan. 1956.
271. LAZENBY, A. The control of rushes. Commonwealth Bur. Pastures & Field Crops. Herbage Abs. 26:71–77. Ref. June 1956.
272. LEE, O. C. Turf. No. Cent. Weed Control Conf. Res. Rpt. 12:129–133. 1955.
273. MCCARTY, M. K. Weed and brush control in pastures. No. Cent. Weed Control Conf. Proc. 12:74–76. 1955.
274. MCCARTY, M. K., and SAND, P. F. Control of hairy chess Bromus commutatus Schrad. in a warm season grass pasture. No. Cent. Weed Control Conf. Proc. 12:28–29. 1955.
275. PEABODY, D. V., and JOHNSON, C. M. Annual weed control in new forage Down Earth 11(4):6–7. Spring 1956.
276. PRESCOTT, L. H. The control of weeds and brush in Louisiana pastures with herbicides. Diss. Abs. 15:1990. Nov. 1955.
277. SCOTT, D. B. The war on weeds. West. Dairy J. 12(7):39–40. May 1956.
278. SPRAGUE, M. A. Easier renovation with less disking. Hoard's Dairyman 101:670. July 10, 1956.
279. SYLWESTER, E. P. For better pastures—kill weeds and brush. Hoard's Dairyman 101:578,599. June 10, 1956.
280. WALKER, C. Weed control in lawns and playing greens. New Zeal. Weed Control Conf. Proc. 8:96–100. 1955.
281. YEATES, J. S. Weeds on the sheep farm; the scope and limitations of chemical control. Massey Agr. Col. Sheepfarming Annu. 1955:99–109.

4. *Weeds in specialized areas (ditches, etc.)*

282. ABEL, A. L. Controlling perennial grasses by combined operations. Agr. Rev. 11:32–37. June 1956.
283. BANFIELD, G. L. Weed control in drains. New Zeal. Weed Control Conf. Proc. 8:77–80. 1955.
284. GARMHAUSEN, W. J. Chemical weed control on Ohio's highways. No. Cent. Weed Control Conf. Proc. 12:61–62. 1955.

5. *Woody plants*

285. ALLISON, D. V., and RECHENTHIN, C. A. Root plowing proved best method of brush control in south Texas. J. Range Mangt. 9:130–133. May 1956.
286. BEATTY, R. H. Control of brush on rights-of-way. No. Cent. Weed Control Conf. Res. Rpt. 12:163–165. 1955.
287. BOLAR, M. D. Tree girdling in Arkansas. Soil Conserv. 21:225–226. May 1956.
288. CHAIKEN, L. E. A new look at the control of undesirable hardwoods. Forest Farmer 15(1):18,24. Oct. 1955.

289. COUDER DE SAINT-CHAMANT, M. L'activité du Groupement d'Economie Montagnarde d'Auvergne en 1954. Féd. Franç. d'Econ. Alpestre. B. (n.s.) 5:97–101. 1955/56.
290. ELDER, C. Kill brush with aerial applications of chemicals. Hoard's Dairyman 101:487. May 10, 1956.
291. ELWELL, H. M., and COX, M. B. Effect of cutting and herbicidal treatment on control of oak sprouts. No. Cent. Weed Control Conf. Proc. 12:63. 1955.
292. GRIFFITHS, A. E., and GOULD, W. P. Chemical control of woody plants in Rhode Island. R. I. U. Agr. Ext. Mimeo. C. 112, 5 p. Aug. 1955.
293. GRIMSRUD, O. S. Why weed in forest nurseries? (In Norwegian.) Arsskr. f. Norske Skogplantesk. 1955:129,131. 1956.
294. HANSEN, H. L. Control of Brush in forests, tree plantations and farm woodlands. No. Cent. Weed Control Conf. Res. Rpt. 12:166–168. 1955.
295. IWAMURA, M. Applications of herbicide for forestry. I. (In Japanese.) Saikyo U. Facul. Agr. Sci. Rpt. 7:73–76. Sept. 1955.
296. JOHNSTON, W. Control of difficult scrub weeds. New Zeal. Weed Control Conf. Proc. 8:61–64. 1955.
297. MATSUI, Z., and SHINOHARA, H. The efficacy of chemical weed killers on each deciduous stem. (In Japanese.) Hokkaido. Forest Expt. Sta. Spec. Rpt. 5:94–102. Jan. 1956.
298. MCCULLY, W. G. Soil injection of herbicides for controlling individual brush plants. Tex. Agr. Expt. Sta. Prog. Rpt. 1869,5 p. Apr. 27, 1956.
299. OWENS, C. B. Chemical eradication of turkey oak [Quercus laevis]. Down Earth 11(4):23–24. Spring 1956.
300. REYNOLDS, H. G., and TSCHIRLEY, F. H. Get rid of those mesquite—now. Ariz. Stockman 22(7):15, 31, 36. July 1956.
301. ROY, D. F. Killing tanoak [Lithocarpus densiflorus] in northwestern California. U. S. Forest Serv. Calif. Forest & Range Expt. Sta. Forest Res. Notes 106, 9 p. Apr. 20, 1956.
302. RYEN, J. Weed control in forest nurseries. (In Norwegian.) Arsskr. f. Norske Skogplantesk. 1955:133–135. 1956.
303. SAMPSON, A. W., and SCHULTZ, A. M. Control of brush and undesirable trees. Unasylva 10:19–29. (Cont.) Ref. 1956.
304. SILKER, T. H. Procedures for prescribed burning in pine-hardwood stands and slash pine plantations for the control of undesirable hardwoods. Tex. Forest Serv. C. 47, 6 p.-folder. Apr. 1955.
305. SILKER, T. H., and DARROW, R. A. Hardwood control and increased forage production in scrub hardwood-pine stands treated with aerial applications of 2,4,5–T and silvex. Tex. Agr. Expt. Sta. Prog. Rpt. 1852, 5 p. Feb. 24, 1956.
306. SOSTER, P. Weed control and herbicides in forest nurseries. (In Italian.) Monti e Boschi 7:255–260. June 1956.
307. TINKER, F. A. Reclamation by fire. Amer. Cattle Prod. 38(2):9–10. July 1956.
308. WALKER, A. H. Killing brush from the air. Cattleman 42(12):42–43. May 1956.
309. WORLEY, D. P., BYRNES, W. R., and BRAMBLE, W. C. Basal sprays kill brush. Sci. Farmer [Pa. Sta.] 3(3):10. Winter 1955/56.

6. *Aquatic weeds*

310. MACMULLAN, R. A., and HARGER, E. M. Control of undesirable plants in waterfowl projects. No. Cent. Weed Control Conf. Proc. 12:58–59. 1955.
311. SCHOLZ-GÜNTHER, E. Bekämpfung der zaunwinde [Convolvulus sepium] in korbweidenkulturen. Berlin. Biol. Bundesanst. f. Land- u. Forstwirt. Mitt. 85:198–200. Mar. 1956.
312. WELTE, E. Einsatzmöglichkeiten von natriumtrichloracetat zur bekämpfung von schilf und verschiedenen sauergräsern. Berlin. Biol. Bundesanst. f. Land- u. Fortswirt. Mitt. 85:187–189. Mar. 1956.

7. *Specific weeds*

313. AGADZHANIAN, G. KH. Biology of Johnson grass [Sorghum halepense] and measures for controlling it. (In Russian.) Akad. Nauk. Armianskoĭ SSR. Izv. Biol. i Sel'skokhoz. Nauk. 9(1):43–47. Jan. 1956.

314. ANDERSON, L. E. Chemical control of Johnsongrass [Sorghum halepense]. No. Cent. Weed Control Conf. Proc. 12:39–40. 1955.
315. ARMONI, S., and others. Control of Bermuda grass in irrigated areas. (In Hebrew.) Hassadeh 36:638–639. (Cont.) May 1956.
316. BALFOUR, P. J. Ragwort [Senecio jacobaea] control. New Zeal. Weed Control Conf. Proc. 8:13–15. 1955.
317. BIGNOLI, D. P., and GONZALEZ LAGUINGUE, E. Sugestiones para controlar el cardo de castilla (Cynara cardunculus). Soc. Rur. Argentina. An. 90:55–58. Feb. 1956.
318. BUCHHOLTZ, K. P. Kill quack grass with dalapon. Hoard's Dairyman 101: 471. May 10, 1956.
319. BYLTERUD, A. Bigsting nettle. (In Norwegian.) Norsk Landbr. 22:236–237. May 11, 1956.
320. CLARKE, E. A. Some observations on bringing in gorse country. New Zeal. Weed Control Conf. Proc. 8:58–60. 1955.
321. COLLIN, F. H. Control of barley grass [Hordeum murinum] in Hawkes Bay. New Zeal. Weed Control Conf. Proc. 8:23–27. 1955.
322. DANIEL, W. H. Control of crab grass in the Midwest. Amer. Nurseryman 103(10):24,26,28,30. May 15, 1956.
323. DAY, B. E., and SWEZEY, A. W. Control of Phragmites with dalapon. Down Earth 11(4):17–19. Spring 1956.
324. DERSCHEID, L. A. Leafy spurge [Euphorbia esula] and russian knapweed [Centaurea repens]. No. Cent. Weed Control Conf. Res. Rpt. 12:14–23. 1955.
325. DERSCHEID, L. A., WALLACE, K. E., and NASH, R. L. Competition, cultivation and chemicals to eliminate leafy spurge. No. Cent. Weed Control Conf. Proc. 12:42–44. 1955.
326. DRAKE, F. R., and KEHOE, J. K. "Manuka" control in East Gippsland. J. Agr. [Melbourne] 54:49–52, 60. Feb. 1956.
327. DUNHAM, R. S. Annual, winter annual, and biennial weeds. No. Cent. Weed Control Conf. Res. Rpt. 12:52–82. 1955.
328. ESBO, H. Watch out for wild oats. (In Swedish.) Lantbrtidskr. f. Dalarna 2:44–46. Apr. 1956.
329. FLETCHALL, O. H. Johnsongrass [Sorghum halepense] and Bermuda grass. No. Cent. Weed Control Conf. Res. Rpt. 12:35–37. 1955.
330. FORSYTH, R. L., JONES, L. G., and HARVEY, W. A. Field sandbur [Cenchrus pauciflorus] and its control. Calif. U. Agr. Ext. L. 55,8 p.-folder. Nov. 1955.
331. FRIESEN, G. The effect of several chemicals applied in the fall for the control of wild oats [Avena fatua]. No. Cent. Weed Control Conf. Proc. 12:22–23. 1955.
332. FRIESEN, H. A. Toadflax [Linaria vulgaris] and other perennial herbaceous weeds. No. Cent. Weed Control Conf. Res. Rpt. 12:24–34. 1955.
333. FRYER, J. D., and CHANCELLOR, R. J. Ragwort [Senecio jacobea] and its control. Gt. Brit. Min. Agr. Fisheries & Food. Agriculture 63:65–69. May 1956.
334. FULTS, J. L. The selective action of chlordane against hairy crabgrass (Digitaria sanguinalis (L.) Scop.) Colo.-Wyo. Acad. Sci. J. 4(7):50. Dec. 1955.
335. GLUE, D. I. Water hyacinth [Eichhornia crassipes] in New Zealand. New Zeal. Weed Control Conf. Proc. 8:81–86. 1955.
336. GOL'D, T. M. Species of dodder (Cuscuta) in the environs of the City of Odessa. (In Ukrainian.) Bot. Zhur. [Kyiv] 12(4):98–101. Ref. 1955.
337. GORDON, R. B. Recent work on dock control using hormone weedicides. New Zeal. Weed Control Conf. Proc. 8:16–22. 1955.
338. GRIGSBY, B. H., REIMER, C. A., and CUTLER, W. A. Further studies on the use of Dalapon for the control of cattail [Typha]. No. Cent. Weed Control Conf. Proc. 12:60–61. 1955.
339. HAM, G. F., BONDARENKO, D. D., and WILLARD, C. J. Controlling Canada thistle with late fall treatments of herbicides. No. Cent. Weed Control Conf. Proc. 12:36–37. 1955.
340. HANSEN, K. Control of wild oats in grain. (In Danish.) Landbonyt 10:255–258. May 1956.

341. HELGESON, E. A. Quackgrass [Agropyron repens]. No. Cent. Weed Control Conf. Res. Rpt. 12:38–51. 1955.
342. HYDER, D. N., SNEVA, F. A., and CALVIN, L. D. Chemical control of sagebrush larkspur. J. Range Mangt. 9:184–186. July 1956.
343. KHAMITOVA, S. Experiments in dodder [Cuscuta] control on alfalfa seed plots in Tadzhik SSR. (In Russian.) Khlopkovodstvo 5(5):48–50. May 1956.
344. KROSBY, P. Wild oats—a weed to be watched. (In Norwegian.) Norsk Landbr. 22:252–254. May 25, 1956.
345. LANTZ, H. L. Chemical control of crab grass in lawns, golf greens and other turfgrass areas. No. Cent. Weed Control Conf. Proc. 12:53. 1955.
346. LEE, O. C. Response of Canada thistle (Cirsium arvense) to amino triazole. No. Cent. Weed Control Conf. Proc. 12:35–36. 1955.
347. LEONARD, O. A. Studies of factors affecting the control of chamise (Adenostoma fasciculatum) with herbicides. Weeds 4:241–254. Ref. July 1956.
348. LOGAN, R. Now you can control your Johnsongrass! Farm Mangt. 5(6):33. June 1956.
349. MEADLY, G. R. W. Bathurst burr (Xanthium spinosum L.). West. Austral. Dept. Agr. J. (ser.3)5:161–164. Mar./Apr. 1956.
350. MEADLY, G. R. W. Geraldton carnation weed or false caper (Euphorbia terracina L.). West. Austral. Dept. Agr. J. (ser.3)4:705–707. Nov./Dec. 1955.
351. METLIN, IU. B. Methods of control of carrot weeds. (In Russian.) Sad i Ogorod 5:25–29. May 1956.
352. MEYER, S. Common coltsfoot (Tussilago farfara L.). (In Italian.) Romagna Agr. e Zootec. 41:61–63. Feb. 1956.
353. NYLUND, R. E., and STADTHERR, R. Studies on the control of crabgrass [Digitaria spp.] in bluegrass lawns. No. Cent. Weed Control Conf. Proc. 12:53–55. 1955.
354. NYLUND, R. E., and STADTHERR, R. Studies on the control of crabgrass [Digitaria spp.] in bluegrass lawns. Weeds 4:264–274. Ref. July 1956.
355. OLSEN, H. K. Control of wild oats. (In Danish.) Landbonyt 10:291–293. June 1956.
356. PHILLIPS, W. M. Field bindweed [Convolvulus arvensis]. No. Cent. Weed Control Conf. Res. Rpt. 12:9–10. 1955.
357. PHILLIPS, W. M. Are you killing your bindweed? Why not. No. Cent. Weed Control Conf. Proc. 12:70–72. 1955.
358. SAND, P. F. Hoary cresses [Cardaria draba] and bur ragweed [Franseria tomentosa]. No. Cent. Weed Control Conf. Res. Rpt. 12:11–13. 1955.
359. SKINNER, S. O., and ANDERSON, J. The giant sensitive plant [Mimosa pudica]. Cane Growers' Q. B. 19:118–123. Apr. 1, 1956.
360. SLIFE, F. W. Control of giant foxtail. Soybean Digest 16(5):12–13. Mar. 1956.
361. THAKUR, C., NEGI, N. S., and SINGH, H. N. Tillage control of nut grass [Cyperus rotundus] in relation to its organic reserves. Bihar Acad. Agr. Sci. Proc. 4:67–74. 1955.
362. VAUGHAN, G. T. Crabgrass—is it here to stay? Pop. Gard. [New York] 7(6):26–27. June 1956.
363. VENKATARAMANI, K. S. The control of Imperata grass. Planters' Chron. 51:293–294. June 1, 1956.
364. WEBER, A. Erfolgreiche bekämpfung [Colchicum autumnale] der herbstzeitlosen auf dem grünland. Gesunde Pflanzen 8:53–54. Mar. 1956.
365. WEBSTER, G. Poison ivy—the three fingered menace. Nat. Hist. 65:248–251. May 1956.
366. WIESE, A. F., and REA, H. E. Chemical control of blueweed [Helianthus ciliaris]. Tex. Agr. Expt. Sta. Prog. Rpt. 1862,3 p. Apr. 4, 1956.
367. WIESE, A. F., and REA, H. E. Chemical control of Texas blueweed [Helianthus ciliaris]. No. Cent. Weed Control Conf. Proc. 12:39. 1955.
368. WILLARD, C. J. Canada thistle (Cirsium arvense). No. Cent. Weed Control Conf. Res. Rpt. 12:1–8. 1955.
369. WILLIAMS, R. H. Salvinia auriculata Aubl.: the chemical eradication of a serious aquatic weed in Ceylon. Trop. Agr. [St. Augustine] 33:145–157. Apr. 1956.

370. ZICK, W. H., and BUCHHOLTZ, K. P. The influence of nitrogen fertilization on the control of quackgrass with herbicides. No. Cent. Weed Control Conf. Proc. 12:40–42. 1955.
371. ZICK, W. H., and BUCHHOLTZ, K. P. The influence of stage of growth on the control of quackgrass with maleic hydrazide. No. Cent. Weed Control Conf. Proc. 12:2–3. 1955.

C. Biological

IV. CHEMICAL AND BIOCHEMICAL INVESTIGATIONS

V. SPECIAL CHARACTERISTICS OF WEEDS

A. Poisonous Plants and Their Control

372. DYER, R. A. Poisonous plants. Farming So. Africa 32:10,39. Apr. 1956.
373. KINGSBURY, J. M. Northeast's poison plants. Rur. New Yorker 106:450,456. July 7, 1956.
374. MARTIN PADIAL, A., and MARIN AVILA, B. Determinación de glucosidos cianogenéticos en determinadas plantas. B. de Zootecnia 11:335–339. Nov. 1, 1955.
375. SPERRY, O. E. The distribution and control of poisonous range plants in Texas. Sheep & Goat Raiser 36(7):18–22. Ref. Apr. 1956.
376. SPERRY, O. E. Distribution and control of poisonous range plants in Texas. II. Poisonous plants of the composite family. Sheep & Goat Raiser 36(10):16–21. Ref. July 1956.

B. Uses of Weeds

C. Pathological and Entomological Relationships

VI. NATURE AND PROPERTIES OF CHEMICALS USED AS HERBICIDES

377. ADDICOTT, F. T., SEKERA, G., and LYNCH, R. S. Defoliants and abscission in cotton explants. Beltwide Cotton Defoliation Conf. Proc. 9:76–83. 1955.
378. BYLTERUD, A. Hormone preparations against brush. (In Norwegian.) Skogeieren 43:153–154. Apr. 15, 1956.
379. CALAVAN, E. C., DEWOLFE, T. A., and KLOTZ, L. J. 2,4–D damage to young citrus; young lemon, orange, and grapefruit trees may be severely damaged by direct application of, or by the drift of 2,4–D. Calif. Agr. 10(4):13–14. Apr. 1956.
380. CARNS, H. R., HAGSKAYLO, J., and EMBRY, J. L. Relation of an indole-3 acetic acid inhibitor to cotton boll development. Beltwide Cotton Defoliation Conf. Proc. 9:65–68. 1955.
381. CIFERRI, R. Chemistry of the ethylene bisdithiocarbamates. (In Italian.) Not. sulle Mal. delle Piante 35/36:29–30. 1956.
382. CRANE, J. C. Growth regulators on apricots; tests with several regulators indicate 2,4,5–T is best for increasing size, hastening maturity, controlling fruit drop. Calif. Agr. 10(4):7,15–16. Apr. 1956.
383. DAVIS, D. E. Some factors that affect the phytotoxicity of water-soluble DNBP. Weeds 4:227–234. July 1956.
384. DUTTON, W. C. New herbicides. No. Cent. Weed Control Conf. Res. Rpt. 12:173–177. 1955.
385. DYBING, C. D., and FULTS, J. L. Phenolic substances in plants and the herbicidal action of 2, 4–dichlorophenoxyacetic acid. Colo.-Wyo. Acad. Sci. J. 4(7):51. Dec. 1955.
386. ESCRITT, J. R. Calcium cyanamide for the preparation of weed-free composts and seed beds. Sports Turf Res. Inst. J. 9(31):85–89. 1955.
387. FIEDLER, G. Erfahrungen mit herbicid Leuna M. Deut. Landwirt. 7:197–199. Apr. 1956.
388. HALL, W. C. Growth inhibition by amino triazole. Beltwide Cotton Defoliation Conf. Proc. 9:51–52. 1955.
389. HAMM, P. C., AMICO, J. J. D'., and HARMAN, M. W. Thio-esters of N-substituted dithiocarbamic acid as selective herbicides. No. Cent. Weed Control Conf. Proc. 12:8–9. 1955.

390. HAMM, P. C., and SPEZIALE, A. J. Relation of herbicidal activity to the amide moiety of N-substituted alpha-chloroacetamides. J. Agr. & Food Chem. 4:518–522. June 1956.
391. HOLSTUN, J. T., and LOOMIS, W. E. Leaching and decomposition of 2,2–dichloropropionic acid in several Iowa soils. Weeds 4:205–217. Ref. July 1956.
392. JAWORSKI, E. G. Biochemical action of CDAA, a new herbicide. Science 123:847-848. May 11, 1956.
393. JOHNSON, M. K., MAGEE, L. A., and COLMER, A. R. Some factors affecting the respiratory response of Azotobacter to 2,4–D and related compounds. Appl. Microbiol. 4:109–113. Ref. May 1956.
394. KEYSER, H. R. Retention of high rates of 2,4–D in the soil. No. Cent. Weed Control Conf. Proc. 12:30–32. 1955.
395. LÜDECKE, H. Eine seltene, im jahre 1955 häufiger aufgetretene wachstumsstörung an zuckerrüben. Nachrbl. des Deut. Pflanzenschutzdienstes 7:201–202. Dec. 1955.
396. LYNCH, P. B. Grass-killing chemicals: recent results in the control of grass weeds in New Zealand. New Zeal. Weed Control Conf. Proc. 8:105–110. 1955.
397. PAVLYCHENKO, T. K. Amino-triazole in controlling perennial weeds. No. Cent. Weed Control Conf. Proc. 12:37–39. 1955.
398. PERLASCA, G. Chemical control of sprouting in white potatoes. Amer. Potato J. 33:113–133. Ref. Apr. 1956.
399. SALGUEIRO, T. A. Considerations on the world of chemistry. (In Portuguese.) Agros [Pelotas] 39:7–15. Jan./Feb. 1956.
400. SILVA, S., and VICENTE, J. Some effects of foliar applications of maleic hydrazide on Guineagrass [Panicum masamum]. Agron. J. 48:275–276. June 1956.
401. SPEZIALE, A. J., and HAMM, P. C. Preparation of some new 2–chloroacetamides. Amer. Chem. Soc. J. 78:2556–2559. June 5, 1956.
402. THOMPSON, F. B. Principles of pre-emergence weed control. New Zeal. Weed Control Conf. Proc. 8:87–91. 1955.
403. THORNTON, B. J. Soil sterilents in weed control. Colo.-Wyo. Acad. Sci. J. 4(7):51–52. Dec. 1955.
404. TSENG, C. J., and YANG, Z. R. Effect of 2,4–D—application on wheat. (In Japanese.) Formosan Sci. 9:45–60. 1955.
405. VEATCH, C. Weed control—1956 suggestions. W. Va. Agr. Expt. Sta. Cur. Rpt. 13,11 p. Apr. 1956.
406. WARD, R. K. Wheat tolerance to hormone weedkillers. New Zeal. Control Conf. Proc. 8:114–118. 1955.
407. YEATES, J. S. Crop tolerance trials with TCA. New Zeal. Weed Control Conf. Proc. 8:111–113. 1955.
408. ZIMMERMAN, P. W., and HITCHCOCK, A. E. Plant growth-regulating effect of 1,1–difluoroethylene (Genetron 150) applied to plants. Boyce Thompson Inst. Contrib. 18:295–297. Apr./June 1956.

VII. EFFECT OF HERBICIDES ON SOILS, LIVESTOCK, AND HUMANS

409. BALDACCI, E., and AMICI, A. Reaction of molds, actinomycetes and seeds of higher plans to M. C. P. A. (In Italian.) Nuovo Gior. Bot. Ital. (n.s.) 62: 362–364. 1955.
410. CRUZ-PAIXAO, J. DA, and DOBEREINER, J. Action of 2,4–D (amine) on microorganisms of various types of soils. (In Portuguese.) Portugaliae Acta Biol. Sér. A 4:243–248. Ref. 1955.
411. DANIELSON, L. L. The crop toxicity period of CMU in a sandy clay loam soil. Weeds 4:255–263. Ref. July 1956.
412. DOBEREINER, J., and CRUZ-PAIXAO, J. DA. Action of the selective herbicides Agroxone, Ervaxone, and Diphenox A on soil microflora. (In Portuguese.) Portugaliae Acta Biol. Sér. A 4:264–271. 1955.
413. FLETCHER, W. W. Effect of hormone herbicides on the growth of Rhizobium trifolii. Nature [London] 177:1244. June 30, 1956.
414. GERRETSEN, F. C. The influence of boron on the growth of Azotobacter chroococcum. Cong. Internaz. di Microbiol. Atti 6(6):314–316. 1953, pub. 1955.

415. PERSIDSKY, D. J., and WILDE, S. A. Effect of eradicants on the microbiological properties of nursery soils. Wis. Acad. Sci. Arts & Let. Trans. 44:65–73. 1955, pub. Apr. 13, 1956.

VIII. EQUIPMENT, METHODS OF APPLICATION, AND HERBICIDAL CALCULATIONS

416. AKESSON, N. B., and SCIARONI, R. H. New air powered hand duster; use of compressed air to fluidize dusts permits treatment of 7,000 square-foot-capacity glasshouse in less than half hour. Calif. Agr. 10(3):3–4. Mar. 1956.
417. BLACK, D. T. Effect of pesticides on spray equipment. No. Cent. Weed Control Conf. Proc. 12:21. 1955.
418. BOWERS, W. How to select a farm sprayer. Hoard's Dairyman 101:675. July 10, 1956.
419. CIFERRI, R. Containers and pumps contaminated by weed-killers. (In Italian.) Prog. Agr. 2:131–132. Feb. 1956.
420. DIDARIO, A., INGERSON, H. G., and LEWIS, D. P. Large spraying and dusting equipment. Pest Control 24(7):9–10,12. July 1956.
421. EDMOND, D. The selective spraying of herbicides. New Zeal. Weed Control Conf. Proc. 8:92–95. 1955.
422. EDWARDS, C. J. Machinery needs which must be met. Power Farmer 16: 288–289. Apr. 1956.
423. FREEMAN, J. A. Panel—the application of herbicides. Brit. Columbia Agron. Assoc. Conf. Rpt. 1956:27–29.
424. HENRY, J. E. Report of studies of a metering device and Venturi type distributor for agricultural aircraft. No. Cent. Weed Control Conf. Proc. 12:19. 1955.
425. HUGHES, E. C. Calibration of weed control spray equipment. (Abs.) Brit. Columbia Agron. Assoc. Conf. Rpt. 1956:33.
426. IMAI, M., and others. Study on the power sprayer. I. (In Japanese.) Soc. Agr. Mach. Japan. J. 17:146–148. Mar. 1956.
427. ISOBE, M., and ISOBE, S. On the corrosion resistance of metallic materials by agricultural chemicals. V. (In Japanese.) Soc. Agr. Mach. Japan. J. 17:143–145. Mar. 1956.
428. KAEGEBEIN, E. W. Old times to the present in spraying and dusting equipment. Ill. State Hort. Soc. Trans. 89:143–146. 1955.
429. KOVTANIUK, M. Spraying spring wheat plantings with 2,4–D preparation in a mixture with mineral fertilizers, translated by V. Makarenko. 1956. 3 p.
430. LARSON, R. E. Data on the use of the handgun for basal applications for brush control. No. Cent. Weed Control Conf. Proc. 12:63–64. 1955.
431. SHAFER, N. E. Installation and performance of a hydraulic drive in a Piper PA-18A. No. Cent. Weed Control Conf. Proc. 12:19–20. 1955.
432. TUNSTALL, A. C. Spraying machines for the small-scale farmer. World Crops 8:230–232,240. June 1956.
433. WEIGHT, W. K. Aquatic weed control practice in potable water supply reservoirs. Weeds 4:235–240. July 1956.

IX. LEGAL ASPECTS

434. CANADA. DEPT. OF AGRICULTURE. PRODUCTION SERV. PLANT PRODUCTS DIV. 1956 list of herbicidal products registered as of May 15, 1956, by K. K. Bragg. Ottawa, 1956. 31 p.
435. GILBERT, C. J. How to bring about a better and more uniform enforcement of the weed laws. No. Cent. Weed Control Conf. Proc. 12:11–13. 1955.
436. MILES, G. P. L. Who takes the blame if spraying causes damage? Power Farmer 16:319. Apr. 1956.
437. RENNEY, A. J. Some hazards connected with the application of herbicides. Brit. Columbia Agron. Assoc. Conf. Rpt. 1956:30–32.
438. WOESTEMEYER, V. W. State weed laws in action. No. Cent. Weed Control Conf. Proc. 12:14–16. 1955.

AUTHOR AND SUBJECT-TITLE INDEX FOR VOLUME V

PAGE

Alfalfa stands, effect of herbicidal sprays on ... 342
Amino triazole, effects on cotton ... 218
  salts and amino triazole-5-C^{14} studies on pigment production in cotton ... 304
  translocation and fate in plants ... 5
Anderson, Burton R ... 135
Aquatic plants, test for screening chemicals ... 371
Aspects of the decomposition and utilization of maleic hydrazide by bacteria ... 34
Bachman, Verman C ... 135
Bacteria, decomposition and utilization of maleic hydrazide ... 34
Basal spray in the control of bear oak ... 121
Bear oak, use of 2,4,5–T esters on ... 121
Behrens, Richard ... 183
Best, K. F ... 141
Bibliography of weed investigations, April to June, 1956 ... 61
  July to September, 1956 ... 147
  October to December, 1956 ... 263
  January to March, 1957 ... 375
Bramble, W. C ... 121
Bromus secalinus, field and laboratory studies on ... 1
Bromus tectorum, field and laboratory studies on ... 1
Bruns, V. F ... 20, 250
Buchholtz, K. P ... 102, 342
Byrnes, W. R ... 121
Canada thistle, germination of seeds ... 20
Celery, weed control in ... 40
Chambers, P. R ... 100
Chappell, W. E ... 331
Chemical weeding and thinning when using pelletized vegetable seeds ... 227
Chess, field and laboratory studies on ... 1
Christiansen, M. N ... 243
Colmer, Arthur R ... 34
Committee members, Weed Society of America ... 57
Cooke, Anson R ... 25
Cotton, effect of amino triazole on ... 304
  effects of amino triazole on ... 218
  response to herbicides ... 112
  use of pre-emergence herbicides in ... 237
  varieties, response to pre-emergence herbicides ... 243
Crafts, A. S ... 93
Critical evaluation of the use of pre-emergence herbicides for weed control in cotton ... 237
Cruzado, Héctor J ... 133
Curtis, L. F ... 237
Danielson, L. L ... 108
Dean, Edward W ... 135
Decomposition and utilization of maleic hydrazide ... 34
Defoliation, effects of amino triazole on ... 218
Delivery patterns of nozzles, effects of wind on ... 350
Distributor, granular ... 108
Dormancy of seeds ... 1
Dorschner, K. P ... 102, 342
Downy brome grass, field and laboratory studies on ... 1
Droplets, apparatus for the production of ... 197
Effects of amino triazole salts and derivatives on cotton defoliation, growth inhibition and respiration ... 218
Effects of fresh water storage on the germination of certain weed seeds ... 20
Effects of herbicidal sprays on nitrate accumulation in certain weed species ... 206

PAGE
Effect of phenoxy herbicide concentrates applied to cuts of sprouting tree species ... 291
Effects of several herbicides on nitrification in a field soil under laboratory conditions ... 331
Effects of wind on delivery patterns of nozzles used for weed spraying ... 350
Field and laboratory studies on the dormancy and germination of the seeds of chess and downy brome grass ... 1
Field distributor for granular herbicide trials ... 108
Frank, Peter A ... 206
Frans, R. E ... 243
Gentner, W. A ... 75
Germination and growth inhibitors in leafy spurge foliage and quackgrass rhizomes ... 12
Germination of seeds ... 1
Germination of weed seeds ... 20, 175
Giddens, Joel ... 316
Grigsby, B. H ... 1, 175, 206
Growth inhibition, effects of amino triazole on ... 218
Guzman, V. L ... 227, 40
Hale, M. G ... 331
Hall, Wayne C ... 218, 304
Heggeness, H. G ... 12
Herbicidal properties of phenoxyalkylcarboxylic acids ... 75
Herbicidal sprays, effects on nitrate accumulation ... 206
interception by oats ... 342
Herbicides, effect on nitrification ... 331
influence of soil-moisture content on ... 112
Hodgson, Jesse M ... 138
Hudson, Bee ... 371
Hudson, M. S ... 371
Hughes, C ... 243
Hulcher, F. H ... 331
Indyk, Henry W ... 362
Influence of light on the effect of 3–(*p*-chlorophenyl)–1,1–dimethylurea on plants ... 29
Influence of soil-moisture content on the response of cotton to herbicides ... 112
Influence of 2,4–D on the uptake of minerals from the soil ... 25
Influence of various components on the effectiveness of 2,4,5–T sprays ... 183
Inhibition of plant growth by some nitrophenylureas ... 135
Inhibitors of germination and growth ... 12
Interaction of temperature, light and moistening agent in the germination of weed seeds ... 175
Interception of herbicidal sprays by oats and its relation to alfalfa stands ... 342
Investigations of the use of 2,4,5–T esters as a basal spray in the control of bear oak ... 121
Klingman, G. C ... 56
Laboratory test for screening chemicals for toxicity to submerged aquatic plants ... 371
Leaching of monuron from Lakeland sand soil ... 321
Leafy spurge foliage, germination and growth inhibitors in ... 12
Lembeck, William J ... 34
Leonard, O. A ... 291
Le Tourneau, Duane ... 12
Light, effect on germination of weed seeds ... 175
influence on effect of 3–(*p*-chlorophenyl)–1,1–dimethylurea ... 29
Maleic hydrazide, decomposition and utilization ... 34
McLane, Stanley R ... 135
Melville, D. R ... 237
Method for evaluating the control of waterweeds with herbicides ... 138
Miller, C. S ... 218, 304
Minerals, uptake as influenced by 2,4–D ... 25
Minshall, Wm. Harold ... 29

PAGE
Moistening agent, effect on germination of weed seeds ... 175
Monuron, leaching from soil ... 321
translocation and metabolism in velvetbeans ... 133
Morgan, M. J ... 350
Morning glory, germination of seeds ... 20
Morris, M. P ... 133
Muzik, T. J ... 133
Nitrate accumulation in weed species ... 206
Nitrification, effect of herbicides on ... 331
Nitrophenylureas, inhibition of plant growth ... 135
Nozzles, effect of wind on delivery pattern ... 350
Note on the translocation and metabolism of monuron in velvetbeans ... 133
Oats, interception of herbicidal sprays by ... 342
Orton, L. W ... 350
Parasitic weed, Striga found in North Carolina ... 56
Phenoxyacetic acids, spectrophotometric determination of ... 102
Phenoxyalkylcarboxylic acids, selective herbicidal properties of ... 75
Phenoxy herbicide concentrates, effect on tree species ... 291
Phenylurea herbicides, phytotoxicity in soil ... 93
Phytotoxicity of four phenylurea herbicides in soil ... 93
Pierce, W. C ... 321
Porter, W. K., Jr ... 237
Post-transplanting weed control of celery in organic soils ... 40
Poverty weed, germination of seeds ... 20
Pre-emergence herbicides, response of cotton to ... 243
use in cotton ... 237
Pre-emergence weed control in soybeans ... 362
Quackgrass rhizomes, germination and growth inhibitors in ... 12
Rainfall, effect on leaching of monuron ... 321
Rasmussen, L. W ... 20, 350
Reins, Gunther E ... 197
Respiration, effects of amino triazole on ... 218
Response of certain crops to 2,4–dichlorophenoxyacetic acid in irrigation water 250
Response of selected cotton varieties to pre-emergence herbicides ... 243
Rogers, Bruce J ... 5
Rotating disk apparatus for the production of droplets of uniform size ... 197
Roth, George A ... 197
Russian knapweed, germination of seeds ... 20
Seeds, weights and numbers per plant ... 46
Selective herbicidal properties of several variously substituted phenoxyalkyl-carboxylic acids ... 75
Shaw, W. C ... 75
Sheets, T. J ... 93
Simplifying weed counts ... 141
Soil, effect of herbicides on nitrification in ... 331
leaching of monuron from ... 321
microorganisms, effect of 2,2–dichloropropionic acid on ... 316
moisture content, influence on herbicides ... 112
Some effects of 2,2–dichloropropionic acid on soil microorganisms ... 316
Soybeans, pre-emergence weed control in ... 362
Spectrophotometric method for the determination of several chlorinated phenoxyacetic acids ... 102
Sprays, influence of components on ... 183
Steinbauer, G. P ... 1, 175
Stevens, O. A ... 46
Striga, a serious parasitic weed found in North Carolina ... 56
Storage in fresh water, effect on seed germination ... 20
Sugar beets, response to 2,4–dichlorophenoxyacetic acid ... 250
Temperature, effect on germination of weed seeds ... 175
Test for screening chemicals ... 371
Thinning using chemicals ... 227
Thomas, C. H ... 237

PAGE
Translocation and fate of amino triazole in plants 5
Translocation of monuron 133
Tree species, effect of herbicides on 291
3–(*p*-chlorophenyl)–1,1–dimethylurea, effect on plants 29
2,4–D, influence on the uptake of minerals 25
2,4–Dichlorophenoxyacetic acid, response of crops to 250
2,4,5–T esters in the control of bear oak 121
2,4,5–T sprays, influence of components on 183
2,2–Dichloropropionic acid, effect on soil microorganisms 316
Upchurch, R. P. 112, 321
Velvetbeans, translocation and metabolism of monuron in 133
Waddle, B. A 243
Waterweeds, a method for evaluating the control of 138
Weed control in celery 40
in cotton 237
pre-emergence in soybeans 362
Weed counts, simplifying 141
Weeding by chemicals 227
Weed seeds, interaction of temperature, light and moistening agent on germination of 175
Weed Society of America, committee members 57
Weed species, nitrate accumulation in 206
Weights of seeds and numbers per plant 46
Westmoreland, W. G. 56
White top, germination of seeds 20
Wind, effect on delivery patterns of nozzles 350
Worley, D. P 121
Worsham, A. D. 316

W. F. HUMPHREY PRESS INC.
GENEVA, N. Y.

Suggestions for Contributors to WEEDS

Manuscripts dealing with all aspects of weed control, regulatory, educational and research, are accepted for publication in WEEDS. Manuscripts should have more than purely local interest. The material described should be more conclusive than progress reports. Articles must be original material previously unpublished elsewhere. Prior publication in brief abstract form is permitted. After review, each manuscript will be accepted for publication upon recommendation of the Editorial Board. The author has the opportunity to make revisions after the review is completed and before publication. Refer to a recent issue of WEEDS to determine details of style to be used.

Manuscripts. Two copies, one on bond paper, should be furnished for each manuscript. The entire text should be double spaced. An additional copy of the manuscript should be retained by the author to ensure against loss.

Use as short a title as practical. Following the title give the authors name(s). It is desirable to divide the manuscript into sections with headings such as Introduction, Methods and Materials, Results, Discussion, Summary and Literature Cited. Avoid underscoring headings, words or phrases unless you wish them to be printed in italics.

Measurements such as time, weight and degrees should be in arabic numerals regardless of the number of digits in the number. Where the figure is not one of measurement, figures below 10 should be spelled out except when one figure in a series has two digits in which case all should be in arabic.

All chemicals mentioned should be described fully the first time used. Nomenclature, abbreviations and definitions should follow those presented in the Terminology Committee Report, WSA, published in WEEDS 4:278–284, July, 1956.

Footnotes. Use footnotes sparingly for items that cannot be included conveniently in the text. The place where the study was done and the address of the author(s) should be given as footnotes. Number footnotes to the text consecutively throughout the manuscript with superscript arabic numerals. Designate footnotes to the tables with superscript lower case letters.

Figures. Experimental data may be presented in graphic or tabular form. However, figures should not be used if they merely illustrate material presented in the text or in tables. Prepare illustrations with approximately the same proportions as a printed page, $4^1/_8 \times 7$ inches, or some fraction of a page. Photographs should be clear glossy prints and should be trimmed of unessential portions.

Graphs and drawings should be inked with heavy black lines to ensure clarity after reduction in size. Hand lettering should be large and made with a lettering guide. Typing is not acceptable. Place the author's name and figure number on the back of each one submitted. Type the legend for each figure on a separate sheet. Figures should be numbered consecutively in arabic numerals.

Tables. Type each table on a separate sheet. Tables should be numbered consecutively in arabic numerals in order of reference in the text. In tables, the caption, column headings and side headings should be in lower case with only the first word and proper nouns capitalized.

Citations. Citations are numbered alphabetically by senior author and the number of the reference is used in the text. Citations should include names of all authors, complete title, volume number, inclusive pages, publication and year. Theses and letters, or any other communication not readily available in libraries, should appear as footnotes.